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Environmental Excellence
HANFORD

Prepared for the U.S. Department of Energy
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EXECUTIVE SUMMARY

This study was initiated to investigate the potential use of phosphatic materials as permeable geochemical barriers for groundwater contaminated with strontium-90 (^{90}Sr). Groundwater discharges to the Columbia River create potential human food chain hazards. It is imperative to immobilize the contamination before it reaches the river. Phosphate materials have been proven by various researchers to be chemical compounds that combine with contaminant metals forming into insoluble metal-phosphate minerals. These minerals are stable and insoluble under normal soil conditions. The U.S. Department of Energy is currently undertaking phosphate stabilization projects at Hanford, Oak Ridge, Savannah, Fernald, and the University of Idaho.

The objective of this study was to demonstrate the precipitation, efficiency of formation, amounts of phosphatic material required for precipitation, and the stability of a strontium-phosphate mineral phase. This bench-scale engineering study will serve to establish the chemical needed for a nominal barrier configuration. The phosphate material reacts with ^{90}Sr in the passing groundwater to create a stable and insoluble strontiapatite mineral.

The soil used in this bench-scale experiment was taken from a depth of 51 to 53 ft in a ^{90}Sr-contaminated well (N-Springs well 199-N-105A). The soil contains 500 pCi/g ^{90}Sr along with smaller amounts of ^{137}Cs, ^{152}Eu, ^{60}Co, and ^{3}H. Heavy metal contamination includes arsenic, cadmium, lead, and selenium above background concentrations.

Batch desorption experiments were conducted to determine the maximum ^{90}Sr concentration as a function of time. Batch adsorption isotherm experiments were conducted on the soil by adding incremental amounts of phosphate material below and above the amounts needed for strontiapatite formation as a function of mineral phase molar ratios. Column tests using ^{90}Sr contaminated soil were performed to examine the pH stability of the formed strontiapatite mineral.

The results indicate that bone char and hydroxyapatite are efficient at sorbing ^{90}Sr from soil and groundwater. The North Carolina apatite failed to be an efficient sorbent material due to its high strontium content. A fourth material, Ash Meadows clinoptilolite (hereafter referred to as clinoptilolite), was also evaluated and proved to be effective in sorbing ^{90}Sr desorbed from soil.

Results from this study indicate that phosphate materials can be effective as permeable barriers for reducing ^{90}Sr concentrations from soil and groundwater.

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ACRONYMS

AAS	atomic absorption spectroscopy
clinoptilolite	Ash Meadows clinoptilolite
EMPS	electron microprobe spectrometry
HAP	hydroxyapatite
IC	ion chromatography
ICP	inductively coupled plasma-mass spectroscopy
INAA	instrumental neutron activation analysis
LSC	liquid scintillation counting
MS	mass spectroscopy
NC apatite	North Carolina apatite
REE	rare earth elements

1.0 INTRODUCTION

This report presents the results of a laboratory study designed to evaluate the ability of phosphatic materials to sorb strontium-90 (^{90}Sr) from soil and groundwater. This investigation was initiated in response to an initiative to evaluate new technologies for use in remedial activities at the Hanford Site. The phosphatic materials were evaluated relative to Ash Meadows clinoptilolite (hereafter referred to as clinoptilolite), a current ion exchange medium used in the remediation of ^{90}Sr contaminated groundwater.

The radionuclide ^{90}Sr is produced by spontaneous fission of uranium-233 (^{233}U) and plutonium-239 (^{239}Pu), which were produced in the reactors at Hanford. The yield of ^{90}Sr from these radionuclides is 6.9 percent and 2.11 percent, respectively. Elevated levels of ^{90}Sr in soil and groundwater are a concern because the element strontium behaves in a manner very similar to calcium in chemical and biological systems. Calcium is an important element in most fauna and is easily adsorbed by organisms from water and other ingested materials. Therefore, it is desirable to control the release of radioactive strontium before it enters the biological and biogeochemical cycle where it can be incorporated in bone and dental tissue. Conversely, the same mechanism that allows ^{90}Sr to incorporate into bone will be examined to test the efficacy of phosphatic materials to stabilize ^{90}Sr.

Previous studies (e.g., Lee, 1961; Anderson, 1971; Moody and Wright, 1995; Carter, 1990) have shown that phosphate materials are effective in precipitating several heavy metals including Pb, Pu, Sr, and U. Phosphate compounds have the ability to incorporate these and other elements into their crystal structure forming a stable, insoluble compound resistant to remobilization by inorganic or organic processes. The half life of ^{90}Sr is 29.1 years. If ^{90}Sr could be effectively complexed and immobilized for several hundred years, elevated concentrations would naturally decay to insignificant levels. The incorporation of ^{90}Sr into a calcium phosphate mineral will possibly result in the formation of strontiapatite, a mineral that is insoluble under normal environmental conditions.

This study used soil from the well 199-N-105A in the 100-N Area. The soil was recovered from a depth of 51 to 53 ft (15.5 to 16 m), known to have a very high concentration of ^{90}Sr. The source of ^{90}Sr was the 1301-N and 1325-N cribs. The concentration of ^{90}Sr at this soil depth was approximately 500 pCi/g. This is the highest ^{90}Sr concentration for 100-N Area borehole sediments (Serne and LeGore, 1996). The soil was used to test the capacity of various phosphate compounds to precipitate ^{90}Sr and investigate the subsequent stability of the phosphate materials under various physical conditions.

2.0 APATITE AND PHOSPHATIC MATERIALS

Phosphatic minerals are important accessory minerals in igneous, metamorphic, and sedimentary rocks. Although typically constituting less then 1 percent of common rocks, phosphate minerals can be a major rock forming phase. For example, sedimentary phosphate rock is dominated by 90 to 95 percent apatite.

The most abundant mineral of the phosphate group is apatite with the chemical composition $Ca_5(PO_4)_3(OH,F,Cl)$. There is a complete isomorphous solid solution between the end-members hydroxyapatite, $Ca_5(PO_4)_3(OH)$, fluorapatite, $Ca_5(PO_4)_3(F)$, and chlorapatite $Ca_5(PO_4)_3(Cl)$. Apatite is an important mineral for environmental remediation because it has a low solubility and a propensity for incorporation of heavy metals into its crystal structure. A recent review of apatite solubility by Chandler and Fuerstenau (1984) indicated a pK_s value of 115. The solubility of apatite with strontium in place of calcium (strontiapatite) is reported to be log K_{sp} -51.3. (Verbeeck, et al, 1977). In field application, strontium movement in soils has been stabilized by the use of phosphate amendments (Anderson, 1971; Francis, 1978). Because of its low tendency to dissolve, it may be one of the most suitable minerals considered for retardation of radionuclides from groundwater.

Various trace elements are readily incorporated into the apatite crystal structure (Liu and Comodi, 1993). Hughes et al. (1991) evaluated the substitution of rare earth elements (REE) into apatite with emphasis on the structural crystallography. Elements of the alkali-earth group are also very compatible with some apatite minerals. For example, fluorapatite can contain over 11 molecular percent SrO (Deer et al., 1992). Although this is a rather unusually high concentration, Edgar (1989) pointed out that many analyses of apatite do not include SrO or BaO, so the actual concentrations of these elements are unknown in many instances.

The crystal structure of apatite belongs to the hexagonal centrosymmetric space group $P6_3/m$. The structure of the lattice can also be degraded to monoclinic symmetries in some chlorapatites when certain anion solid solutions are present (Hughes et al., 1989, 1991). There are two sites for metallic cations: Ca1 which represents a calcium site with six neighboring oxygen atoms (six fold coordination) and Ca2, a calcium site with eight oxygen and one F, Cl, or OH anion (nine fold coordination). Isomorphous substitution can occur in both Ca1 and Ca2 sites by Na, K, Sr, Mg, Ba, Zn, Cd, Sc, Y, the REEs and U.

3.0 DESCRIPTION OF EXPERIMENTS

The experiments were designed to test various geochemical and kinetic responses of different types of sorbent materials in contact with ^{90}Sr in solution. These sorbent materials are listed in Table 3-1. Although not presented in the table, phosphorus pentoxide (P_2O_5) and monocalcium phosphate ($Ca(H_2PO_4)_2 \bullet H_2O$) were tested. The phosphate materials chosen were found by previous studies to be effective in scavenging metals from soil and groundwater. In addition to the natural phosphates, such as North Carolina apatite (NC apatite) and bone char, pure, reagent-grade hydroxyapatite (HAP) was also studied under the same conditions as the phosphate materials to evaluate effects caused by impurities in the natural apatite. A series of experiments were also done with clinoptilolite. This mineral was evaluated to compare the chemical effectiveness of phosphatic material as a geochemical barrier to a current methodology in groundwater contaminant retardation.

After receiving the ^{90}Sr contaminated soil from well 199-N-105A, the soil was air dried, mixed thoroughly, and sieved using a 2 mm ASTM sieve. This was done to ensure a uniform ^{90}Sr concentration in the subsequent experiments.

The experiments as outlined in the scope of work consisted of four discreet steps:

1. The desorption/adsorption study, which focused on the geochemical characterization of simulated groundwater solutions that were in contact with the soil and sorbent material.

2. The kinetics study, which quantified the rate of the sorption reactions.

3. The loading capacity study, which determined the amount of ^{90}Sr adsorbed by different phosphatic materials.

4. The pH stability test for the precipitated ^{90}Sr-phosphate complexes, which examined the stability of different pH conditions and time periods.

3.1 DESORPTION AND ADSORPTION EXPERIMENT

In this portion of the bench scale study, a measured amount of Hanford soil and Hanford simulated groundwater were mixed with incremental amounts of different phosphate materials. When groundwater is in contact with solid mineral phases in soils, its composition is dependent on the initial groundwater concentration, adsorbed and precipitated solutes, desorbed constituents, and dissolved crystals. In order to characterize the groundwater after equilibration, aliquots of the solution were analyzed after varying agitation periods with the soil phosphate mixtures.

A series of preliminary experiments were performed to identify the appropriate amounts of soil and phosphatic materials needed for determining of isotherms. The optimal times for

equilibration of the soil and groundwater were also determined in this phase of the study. Results of these tests are presented in Tables A-3 and A-4. Results indicate that 3 g of soil reacted for 72 hours were sufficient for determining adsorption isotherms and dissolution/precipitation reactions. It was also determined that proportions of sorbent > 10 percent by weight generally did not increase adsorption. Therefore, the range of interest was limited to 0 to 10 percent by weight of adsorbent, and various intervals between these bounds were used for the primary study.

Each of these experiments used 3.00 ± 0.01 g of Hanford soil and 30 mL of Hanford simulated groundwater. The groundwater solution was prepared from double distilled water by adding reagent grade chemicals (Table 3-2) to reproduce the major element abundance of natural groundwater in Hanford soils. In this way changes in the major element composition of groundwater can be related to the sorbent added.

Incremental amounts of sorbent materials were added to the soil and groundwater mixture to determine adsorption isotherms and dissolution/precipitation reactions. A centrifuge tube of each series was agitated for 72 hours in an automatic shaker. The soil was separated from the groundwater by centrifugation. A syringe equipped with a nucleopore filter membrane was used to withdraw the solution. The conductivity and pH were determined at this point using a conductivity meter and pH electrode. Aliquots of the solution were analyzed for ^{90}Sr by liquid scintillation counting (LSC) spectroscopy, for major cationic constituents by atomic absorption spectroscopy (AAS), for minor elements by ICP-MS, and for anion abundances by ion chromatography (IC).

Statistical and analytical uncertainties that occur in any type of batch experiment were avoided by running each series in duplicate. The assumption that the composition of soil and sorbent in each of the vessels is homogeneous was made considering the uniform grain size achieved by sieving the samples. Another assumption is that the reaction containers, which consisted of 60 mL polyethylene tubes, were inert to the system. However, ^{90}Sr and other trace elements could also have been adsorbed or precipitated on surfaces of containers. Because the addition of a strong dissociating mineral acid could not be accomplished in the agitation tube, it is assumed that sorption of the wall may be uniform in all experiments. To minimize these effects in the storage containers that were used to transport groundwater to the analytical instruments, the solution was acidified with dilute ICP-MS grade nitric acid.

3.2 KINETICS OF COMPLEXATION

Adsorption reactions are typically rapid and equilibrate in the order of minutes to hours (Sposito, 1989; Moody and Wright, 1995). Therefore the time intervals for this experiment were chosen to be 1, 3, 5, 10, 15, and 24 hours. Considering the most effective concentration of the sorbent, the composition of the soil/sorbent mixture was selected from the primary adsorption experiment.

Each centrifuge tube was filled with 3 g of soil, the appropriate amount of sorbent material, and 30 mL Hanford simulated groundwater. The vessels were then shaken for the desired agitation

time, the solid phase was separated by centrifugation for 30 minutes, and the supernatant was filtered through a 0.45 μm nucleopore membrane filter.

Conductivity and pH were measured immediately after filtration on 3 mL of the solution. Aliquots of the solution were then analyzed for ^{90}Sr by LSC, major cation components by AAS, and trace element cations by ICP-MS.

3.3 LOADING CAPACITY OF SORBENT MATERIALS

This experiment was performed to quantify the maximum amount of strontium in solution that can be adsorbed by the different sorbent materials. Stock solutions containing concentrations of 0.01, 0.1, 1, and 3 g of strontium nitrate per 30 mL double distilled water were prepared by weighing the appropriate amounts in polyethylene bottles and adding double distilled water.

Centrifuge tubes were filled with 3 g of NC apatite, bone char, hydroxyapatite and clinoptilolite. To each of these tubes 30 mL of the stock solution was added. The solutions were agitated for two days and then filtered through a 0.45 μm nucleopore membrane filter. The concentration of strontium was then analyzed by AAS.

3.4 pH STABILITY TEST OF PRECIPITATED ^{90}Sr-PHOSPHATE MINERALS

The stability of the ^{90}Sr-phosphate was investigated under various pH conditions and reaction times as outlined in the scope of work. The soil was mixed with phosphate and clinoptilolite at proportions that were most effective for the stabilization of the contaminant. A total of 1 kg soil-sorbent mix was used for each experimental condition.

Three replicates of each mixture were prepared by saturating them with Hanford simulated groundwater and allowing the sample to dry to field capacity (0.33 bar). Each of the samples were then incubated for 3 different time periods: 1, 2, and 4 weeks. After incubation, an aliquot of the soil-sorbent mixture was removed and placed in a column. Six columns were prepared to study the column water flow-through for each treatment at pH levels of 5, 6, 7, 8, and 9. A control column that contained soil without added sorbent material was prepared for each of the treatments. A volume of Hanford simulated groundwater equal to 5 pore volumes of material and adjusted for the proper pH was introduced into the columns, then reacted water was analyzed.

During the last phase of this experiment, a saturation extract was performed on 200 g of soil from each column. The soil was saturated with groundwater and the liquid phase was extracted and analyzed for ^{90}Sr, ICP-MS metals, IC anions, pH and conductivity.

3.5 ANALYTICAL METHODS

All of the analyses were performed on the liquid phase. The concentration of ^{90}Sr was measured by LSC, major cations in the groundwater by AAS, minor constituents by ICP-MS, anions by IC and pH and conductivity by electrode probe.

3.5.1 Liquid Scintillation Counting

A volume of 2 mL per sample was mixed with 15 mL of commercial scintillation cocktail (OPTIFLOUR) in 20 mL liquid scintillation glass vials. Prior to counting, ^{90}Sr was equilibrated with its daughter product ^{90}Y for two weeks. A Beckman™ LS 6500 liquid scintillation counter was used for the measurement. Blank samples containing 2 mL of distilled water and cocktail were used to correct for background.

3.5.2 Atomic Absorption Spectrophotometry

Sodium, magnesium, and calcium concentrations in the liquid phase were determined by the AAS method. A Perkin Elmer Model 5000 spectrophotometer was used. The relatively high abundance of these elements in the solution made a dilution to lower concentrations necessary. Dilution of the samples was carried out by adding 0.2 mL of 70 percent HNO_3, 0.41 mL of Cs (1000 ppm), and 14.8 mL of double distilled water to exactly 5 mL of the original sample. The dilution process had to be repeated more than 4 times for some of the samples.

The concentration of elements in the standard solutions is listed in Table 3-3. The standards were run at the beginning, middle, and end of each analytical series. The number of unknowns that were analyzed in sequence did not exceed 22.

3.5.3 ICP-MS Analysis

Five milliliter aliquots of the groundwater solutions were acidified with 0.7 percent HNO_3 to prevent precipitation of solutes on the container walls. An internal standard containing Be, In, and Bi was added to the sample. Standards were prepared from ICP-MS grade solutions. A standard was analyzed for quality control for every eleventh sample of unknown composition. A VG Plasma Quad ICP-MS™ system manufactured by Fisons was used.

3.5.4 Ion Chromatography

The analysis of anions in the groundwater was performed by ion chromatography on an DIONEX™ 2000i ion chromatograph located in the Oregon State University College of Agricultural Sciences. Aliquots of 2-5 mL of the unknown solution were used. The columns consisted of AG4A-SC guard and AS4A separator material. The regeneration of the columns was accomplished by elution with 1.8 m molar Na_2CO_3 and 1.7 m molar $NaHCO_3$ solutions. The solutions were run through the columns at 2 mL/minute.

Standards were prepared from DIONEX™ anion standard stock solutions (Lot # 950623). They contained fluorine, chlorine, nitrate, phosphate, and sulfate. Five standard solutions were prepared (Table 3-4). The accuracy of the analysis was ascertained by repeated runs of standard solution 3. An analysis of that standard was performed after every twelfth unknown sample.

Table 3-1. List of the Adsorbent Materials and Related Properties

Property	NC Apatite	Bone Char	Hydroxyapatite	Clinoptilolite
Formula	$Ca_{10}(PO_4)_6(OH,F)_2$	$Ca_{10}(PO_4)_6(OH,F)_2$	$Ca_{10}(PO_4)_6(OH,F)_2$	zeolite
Origin	phosphate rock	charred animal bone	synthetic chemical	aggregate
Grain Size	180-250 μm	180-250 μm	180-250 μm	180-250 μm
Surface	smooth	porous	not available	porous
Texture	rounded	irregular fragments	plates	rounded
Analysis	INAA and EMPS	INAA and EMPS	INAA	INAA

The surface morphology was examined by scanning electron microscopy and petrographic thin section observation. Chemical analysis were performed by instrument neutron activation analysis (INAA) and electron microprobe spectroscopy (EMPS).

Table 3-2. Concentration of the Solutes in Simulated Hanford Groundwater

Element	Conc. (mmol/L)	Weight (mg/L)	$CaCO_3$ (mmol/L)	$MgCO_3$ (mmol/L)	$NaHCO_3$ (mmol/L)	$CaSO_4$ (mmol/L)	$Ca(NO_3)_2$ (mmol/L)
Ca^{2+}	0.36	14.5	0.12	-	-	0.16	0.08
Mg^{2+}	0.18	4.5	-	0.19	-	-	-
Na^{+}	0.13	3	-	-	0.13	-	-
SO_4^{2-}	0.16	15.7	-	-	-	0.16	-
NO_3^{-}	0.16	10	-	-	-	-	0.16
HCO_3^{-}	0.87	53.1	0.37	0.38	0.13	-	-

The pH of this solution was 8.2 ± 0.1.

Table 3-3. Concentration of Elements in the Standard Solutions Used for Atomic Absorption Spectrophotometry

Element	Standard 1 μg/mL	Standard 2 μg/mL	Standard 3 μg/mL	Standard 4 μg/mL	Standard 5 μg/mL	Standard 6 μg/mL
Sodium	2	4	8	16	24	NA
Calcium	0.32	0.96	1.92	2.88	3.84	5
Magnesium	0.16	0.48	0.96	1.44	1.92	NA

NA = Not applicable

Table 3-4. Concentration of Elements in the Standard Solutions Used for Ion Chromatography

Element	Standard 1 μg/mL	Standard 2 μg/mL	Standard 3 μg/mL	Standard 4 μg/mL	Standard 5 μg/mL
Fluoride	0.20	0.51	1.02	1.53	2.04
Chloride	0.30	0.75	1.51	2.26	3.01
Nitrate	1.01	2.53	5.05	7.58	10.10
Phosphate	1.52	3.80	7.60	11.40	15.20
Sulfate	1.52	3.80	7.60	11.40	15.20

4.0 RESULTS AND DISCUSSION

Summaries of the results of the four experiments are presented in this section. The data from all of the experiments are contained in Appendices A through D.

4.1 ASSUMPTIONS OF THE METHODOLOGY

After receiving the ^{90}Sr contaminated soil from well 199-N-105A, the soil was air dried, mixed thoroughly, and sieved suing a 2 mm ASTM sieve. This was done to ensure a uniform ^{90}Sr concentration in the subsequent experiments. The assumption was made that each of the centrifuge tubes contained a representative sample. Any variations in the composition of the soils would result in errors in the measurements. It should be noted that this assumption may not be valid. The precision of the analytical data was higher than the data points reproduced from duplicate runs. Because only two duplicate analysis were performed in most of the runs, it is statistically unwarranted to calculate the standard deviation of the paired observations. At least 4 to 5 repeated analysis may have to be carried out in order to confidently calculate the errors. A modified experimental approach would be a better solution to the problem of the geological heterogeneity of the samples. However, this approach was not covered in the contractor scope of work. A method to accomplish this is currently under development.

4.2 DESORPTION ISOTHERM

In an effort to determine the amount of ^{90}Sr desorbed from the solid phase during a specific time, a desorption isotherm was executed on the Hanford soil. Two separate desorption isotherms were performed during a seven-day period. Two water-to-soil ratios were used in an effort to determine the effect of varying ratios: the standard water-to-soil ratio of 10:1 and a 5:1 water-to-soil ratio. The results of these two desorption isotherms are presented in Figure 4-1. The analytical data are presented in Table A-1. As seen from the desorption isotherm, the maximum amount of ^{90}Sr desorbed from the soil into the Hanford simulated groundwater is approximately 11,000 pCi/L for the 10:1 water-to-soil ratio isotherm, and occurs at the 72 hour desorption time. For the 5:1 water-to-soil ratio isotherm, the maximum desorbed amount of 12,900 pCi/L was also 72 hours. This is only a 17 percent increase in desorbed ^{90}Sr relative to twice the amount of soil in contact with solution. Data from Table A-1 can be used to calculate the kinetic rate constant Ka, assuming a first order reaction, expressed by the relationship:

$$\log(1-\frac{q_t}{q_e})=-k_a \times t \qquad (1)$$

where

q_i is the amount of ^{90}Sr adsorbed on the soil

q_e the concentration at time t
k_a is the desorption rate coefficient

The experimental results of data from Table A-1 were used to calculate linear regressions. For the experiment with 3 g soil per 30 mL groundwater the desorption rate constant is 0.04/day; whereas, the system representing 6 g of soils is only 0.03/day. This is contrary to the expectation that twice as much sediment will yield double the activity.

An important question is whether ^{90}Sr is actually quantitatively desorbed from the minerals or if the process is only partially completed. The ^{90}Sr concentration in the soil must be known in order to evaluate the hypothesis. Because the activity of the radionuclide is 500 pCi/g, the amount of ^{90}Sr per gram of soil can be calculated as follows:

$$N = \frac{(-dN/dt)}{\lambda} = \frac{-18.5[Bq/g]}{7.58^{-10}[sec^{-1}]} = 2.44 nuclei/g \qquad \textbf{(2)}$$

This concentration can also be expressed in number of isotopes per gram and would be 0.04 pmol/g. Hence a contaminated area measuring 1 x 100 x 100 m contains approximately 9.7 grams of ^{90}Sr. Three grams of soil contain 55.5 Becquerel radiation. However, only in the desorption experiments, between 8.1 and 12 Becquerel of radiation was found in 30 mL of simulated groundwater after one week. Therefore, it can be concluded that only about 21 percent of ^{90}Sr will partition in the liquid phase.

Considering the results of the desorption isotherm, 72 hours will be used as the amount of contact time for the adsorption isotherms. The water-to-soil ratio of 10:1 will be used for the execution of the adsorption isotherm.

4.3 ADSORPTION ISOTHERMS

Adsorption isotherms are important tools for investigating precipitation and adsorption effects of solutes added to a specific solution in increasing amounts. The adsorption isotherm graphically illustrates the precipitation or reduction of the soluble metals when the sorbent is applied to the system. Adsorption is most often described in terms of isotherms, which show the relationship between the effective concentration in solution of the species being adsorbed and the actual amount adsorbed at a constant temperature. When plotted, the shape and the mathematical expression of the isotherm provides a great deal of information concerning the chemistry and sorption mechanisms within the system. The most effective concentration of the sorbent to effect precipitation can be ascertained by examining the sharp downward curves of the isotherm. The system can be modeled thermodynamically by first analyzing the solution components, entering the data into the computer program, and changing the amounts of sorbent in the theoretical system to match those amounts from the adsorption isotherm. The thermodynamic modeling results will be presented in a forthcoming document.

Two adsorption isotherms were determined. A preliminary adsorption isotherm was carried out to find the approximate range of sorbents required to induce precipitation and/or adsorption. The data for the preliminary adsorption isotherm are presented in Tables A-3 and A-4. Hydroxyapatite, bone char, and clinoptilolite effectively reduce the solution concentration of ^{90}Sr. The addition of the phosphate compounds $Ca(H_2PO_4)_2 \cdot H_2O$ and P_2O_5 in the preliminary adsorption isotherm were found to liberate the soil ^{90}Sr into solution. This was undoubtedly due to the pH lowering effect of these two compounds. As a consequence, these two phosphatic compounds were excluded from further experimental consideration. Data collected from the preliminary adsorption isotherm indicates that maximum reduction of ^{90}Sr in solution occurs at sorbent concentrations of less than 10 percent (mass basis). The primary adsorption isotherm was executed using 10 percent as the upper limit of the sorbent concentration. To illustrate distinct departure from linearity and to effectively determine the concentration of sorbent giving rise to the precipitation/adsorption of ^{90}Sr from solution, the number of increasing concentrations of sorbent was increased from the 4 concentrations used in the preliminary adsorption isotherm. Table A-5 presents the concentrations of the added sorbent and the resulting concentration of ^{90}Sr remaining in solution after 72 hours of contact. The adsorption isotherms for NC apatite, hydroxyapatite, bone char, and clinoptilolite are presented in Figure 4-2. The preliminary adsorption isotherm 20 percent sorbent value for ^{90}Sr is presented in Figure 4-2 to add completeness to the linearity.

The starting ^{90}Sr concentration for all of the sorbents (0 percent) is fixed at 12,111 pCi/L (determined from the desorption isotherm. Based on the 72 hour adsorption isotherm, the clinoptilolite appears to have the greatest ability to reduce ^{90}Sr solution concentration. The greatest reduction occurs at clinoptilolite values of less than 2 percent. The amount of ^{90}Sr precipitated and/or adsorbed at 2 percent added clinoptilolite is approximately 85 percent. The bone char is second in efficiency in reducing the ^{90}Sr concentration. All concentrations of bone char reduce ^{90}Sr concentration. However, 85 percent reduction in ^{90}Sr concentration is achieved at higher concentrations of bone char: between 10 and 20 percent. At 20 percent added bone char the ^{90}Sr concentration is nearly the same as the reduction of ^{90}Sr caused by the addition of clinoptilolite. This data shows that bone char can effectively reduce the concentration of ^{90}Sr (as does the clinoptilolite) but at higher values of added bone char.

The remainder of the data generated for the adsorption isotherm experiments are contained in Tables A-5 thru A-7. Data for the major cations calcium, magnesium, and sodium were recalculated to molar abundances, normalized to 100 percent, and plotted in the ternary diagram in Figure 4-3. Hanford groundwater, shown by the hatched circle in the figure, has subequal parts of sodium and calcium with 10 to 15 molar percent magnesium. When NC apatite and hydroxyapatite were added to the system, compositions became enriched in calcium relative to sodium and magnesium. Therefore it can be concluded that small amounts of calcium were introduced by adding apatite. It could be speculated, that to some degree, calcium on the surfaces was exchanged for other cations in the groundwater, but this should be supported by further microscopic study.

Bone char and clinoptilolite behaved differently with respect to sodium and magnesium concentrations. The clinoptilolite added only sodium to the groundwater; whereas, bone char

contributed sodium and calcium. The argument can be made for clinoptilolite, that ion exchange may be the prevailing mechanism to desorb sodium from the crystals. This will be discussed in detail in the loading capacity section.

When 10 percent bone char was added to the system, the magnesium concentration in the liquid phase doubled (Table A-7b). Calcium was strongly adsorbed from the groundwater at concentrations greater than 1.75 percent, and sodium was released into solution at concentrations greater than 1 percent. On a molar basis the amount of sodium dissolved does not match the amount of calcium adsorbed.

The hypothesis of protonation can be tested by analyzing changes in the pH condition of the liquid phase. Exchange of sodium for hydrogen should result in an increased hydroxyl abundance or a higher pH value. The pH for systems containing 20 percent bone char and clinoptilolite becomes 9.5 and 9.17, respectively (Table A-3); whereas, the same amount of NC apatite and HAP have little effect on the pH (8.0 and 8.2 respectively).

The concentration of anionic solutes is also influenced differently by the different materials. Figure 4-4 shows the elements sulfate, chlorine, and fluorine, normalized based on their molar abundances and plotted on a ternary diagram. Nitrate was excluded from the calculations, because its concentration was essentially constant under all experiments (Tables A-6a through A-6e). No determination of bicarbonate or total inorganic carbonate was made. Because carbonate is the major anion in the water, knowing its abundance could assist in the interpretation of the anion behavior.

Chlorine is strongly enriched relative to fluorine and sulfate in the solution when bone char is added. This would support the interpretation that this material may contain small amounts of halite ($NaCl$) or sylvanite ($MgCl_2$) that are simply dissolved when brought into contact with water. Ashing of animal bone and tissue would certainly be a plausible source of soluble alkali salts.

NC apatite has a tendency to increase the fluorine concentration of the groundwater (Figure 4-4). This can be explained by the re-equilibration of fluorapatite with the fluid and dissolving small amounts of the solid. Hydroxyapatite contributed only chlorine to the water because this synthetic mineral does not contain appreciable amounts of fluorine.

With the exception of NC apatite, all the materials that were tested adsorbed ^{90}Sr from the solutions (Table A-5). NC apatite has a very high initial strontium content of 1720 $\mu g/g$ as determined by instrumental neutron activation analysis (INAA) and electron microprobe spectrometry (EMPS). In order to illustrate the sorption characteristics of the earth and alkali metals, the mass excess of sodium, magnesium, calcium, strontium, and barium was plotted against the weight fraction of HAP as a representative mineral for apatite in Figure 4-5. With the exception of strontium, all alkali and alkali earth elements show a mass deficit instead of a surface adsorption. For the lighter elements (Na, Mg, Ca) this is an indication of the ion exchange capacity of HAP. Barium concentrations did not vary significantly and the abundance of this element in the solutions was close to its detection limit. These factors are the main

contributors to the scatter shown in Figure 4-5. The mass excess of strontium follows a Langmuir isotherm on the graph, but at very low weight fractions of HAP the mass excess cannot be determined very accurately. This may be the result of the inherited sample inhomogeneity of the sediment sample. Only at very high concentrations of the homogeneous sorbent does this effect becomes less apparent. Nevertheless, the data indicate that strontium is adsorbed on the surfaces of hydroxyapatite.

The transition metals iron and chromium were desorbed from the system when hydroxyapatite was added (Table A-8c). Manganese showed a behavior different from the other metals. This element apparently will partition in the solid phases when phosphate is added. However, the results of the desorption and preliminary adsorption experiment indicated that manganese is highly reactive between 1 and 7 days. This could be a surface adsorption reaction or a secondary precipitation of manganese hydroxide that is linked to redox reactions in the system. Bone char has a similar effect on the manganese concentrations in the solution. The desoprtion and subsequent precipitation of metals from the placement of in situ barriers like bone char and clinoptilolite may potentially impact the hydraulic conductivity. Further investigation of this scenario is warranted.

The analytical data for zinc, chromium, and copper in NC apatite (Table A-8a) is fairly variable and often at the limit of detection. Therefore the interpretation of these values is very limited.

The question of the actual form in which ^{90}Sr is present in the soils is not a subject of this study. It can be assumed that much of the strontium occurs as surface adsorbed species on the mineral grains in the soil. Diffusion of strontium into the crystal lattices is unlikely under the thermodynamic conditions of the sediment. Strontium may also be present in the form of small strontium carbonate or strontium sulfate precipitates in the soil because the solubility of these minerals is 1.1 mg/L and 1.13 mg/L in cold water, and HCO_3^{2-} is the major anion in the groundwater. Therefore it is to be expected that at lower pH conditions, the concentration of strontium should increase.

4.4 KINETICS OF COMPLEXATION

To test the efficiency of adsorption of the sorbent materials, the amount of ^{90}Sr remaining in solution after the addition of sorbents was examined at various time intervals. The time intervals for contact time were 1, 3, 5, 10, 15, and 24 hours. The amount of ^{90}Sr remaining in solution at each time interval was plotted relative to the control as sorption efficiency. The concentration of ^{90}Sr attributed to the desorption of ^{90}Sr from the soil/sorbent mixture was subtracted from the amount that would be expected in the solution if only soil were present in the system, then these data were plotted as a function of time. The data for ^{90}Sr are presented in Table B-1. These data are presented graphically in Figure 4-6.

Of the materials tested, the clinoptilolite was the most efficient in reducing the solution concentration of ^{90}Sr. At 10 hours, the clinoptilolite has reduced the 13,683 pCi/L ^{90}Sr solution concentration by 88 percent. Bone char reduced the ^{90}Sr concentration by 52 percent. Both

clinoptilolite and bone char illustrate a plateau after the tenth hour of contact, suggesting that maximum adsorption is occurring within the first 10 hours. The addition of NC apatite did not change the desorption rate of ^{90}Sr from the soil, which indicates that the natural apatite is not a suitable material in the stabilization of ^{90}Sr in soils. However, when 5 percent hydroxyapatite or 5 percent bone char were added to the system, a significant reduction in the activity of ^{90}Sr was observed. The kinetics of the complexation is fairly fast. It is noteworthy that the differential rate is similar for bone char and clinoptilolite.

4.5 LOADING CAPACITY EXPERIMENT

The capacity of the sorbent material was measured by adding incremental amounts of strontium nitrate, $Sr(NO_3)_2$, to 3 g of NC apatite, bone char, hydroxyapatite, and clinoptilolite. The contact time for all three concentrations of $Sr(NO_3)_2$ was 48 hours. The distribution coefficient (K_d) was then calculated as the ratio of the strontium concentration adsorbed on the solid phase versus the strontium concentration remaining in the solution. The partition coefficients were then plotted in Figure 4-7. Data generated by this experiment are contained in Table C-1. At low strontium concentrations in the solutions, the cation is strongly adsorbed on most of the minerals. As the abundance of the solute increases, the capacity of the adsorbent decreases. A K_d of less than 1 indicates that more strontium remained in solution than was adsorbed on the crystal surfaces. The K_d values are substantially higher for the clinoptilolite and bone char for all concentrations of the $Sr(NO_3)_2$. The clinoptilolite has slightly higher K_d values than bone char, ranging from 585 at low concentrations of $Sr(NO_3)_2$ to 0.41 for high concentrations of $Sr(NO_3)_2$. The bone char K_ds range from 371 at low concentrations of $Sr(NO_3)_2$ to 0.31 for high concentrations of $Sr(NO_3)_2$.

Differences in K_ds may be substantially affected by surface area of the sorbents. The bone char, supplied by the Tigg Corporation, is reported to have a total surface area of 100 m^2/g. The clinoptilolite, supplied by the American Resource Corporation, Inc., is reported to have a total surface area of 40 m^2/g. Upon initial observation, it would appear that clinoptilolite is the better sorbent of the two, given the fact that the clinoptilolite has substantially lower surface area than bone char. It must be noted that the clinoptilolite and the bone char sorb ^{90}Sr by two different chemical processes. The clinoptilolite is an ion exchanger and as such sorbs ^{90}Sr onto the exchange sites initially occupied by monovalent and divalent cations. The ion exchange process occurs very quickly for the clinoptilolite, as evidenced by the kinetic experiment (Figure 4-6). The fact that ion exchange is occurring is evidenced by the high concentration of Na in the supernatant after the soil-clinoptilolite reaction with water. Na is the primary exchanger cation for the clinoptilolite. The bone char is an apatitic (calcium phosphate) mineral and sorbs ^{90}Sr by incorporating the metal into its crystal formation. This is referred to as isomorphic substitution. Ca is replaced in the crystal structure by the ^{90}Sr. This is evidenced by the elevated Ca levels in the supernatant of the bone char isotherms. The kinetics of the isomorphic substitution is somewhat slower than the ion exchange process, as evidenced by the slower rate of ^{90}Sr sorption for bone char in Figure 4-6. The efficiencies and kinetics of the chemical reactions overshadow the apparent availability of reactive surface area when bone char is compared to clinoptilolite. Hydroxyapatite and NC apatite have less ability to sorb ^{90}Sr than clinoptilolite and bone char.

4.6 pH STABILITY TEST OF ^{90}Sr-PHOSPHATE COMPLEX

The stability of the ^{90}Sr-phosphate complex was investigated under various pH conditions and reaction times as outlined in the scope of work. The soil was mixed with phosphate and clinoptilolite at proportions that were most effective for the stabilization of the contaminant. A total of 1 kg soil-sorbent mix was used for each experimental condition. Three replicates of each mixture were prepared by saturating with Hanford simulated groundwater and allowing the sample to dry to field capacity (0.33 bar). Each of the samples was then incubated for 3 different time periods: 1, 2, and 4 weeks. After incubation, an aliquot of the soil-sorbent mixture was removed and placed in a column. Six columns for each treatment were prepared to study the column water flow-through at pH levels of 5, 6, 7, 8, and 9. A control column that contained soil without added sorbent material was prepared for each of the treatments. A volume of Hanford simulated groundwater equal to 5 pore volumes of material and adjusted for the proper pH was introduced into the columns, and the reacted water was analyzed.

In the first phase of this experiment, a saturation extract was performed on 200 g of soil from each column. The soil was saturated with groundwater and the liquid phase was extracted and analyzed for ^{90}Sr, ICP-MS metals, IC anions, pH and conductivity. The analytical results are presented in Tables D-1 through D-5. Although no control was performed for the saturation extract, the resultant data does indicate the immobilizing capability of the sorbents, especially given the incubation times of 1, 2, and 4 weeks. The percent reduction in solution ^{90}Sr concentration is figured relative to NC apatite stabilization. The data for the resultant ^{90}Sr concentration is plotted in column format and is shown in Figure 4-8. This figure indicates that both bone char-^{90}Sr complex and clinoptilolite at 5-percent additions to the soil are remarkable in reducing the solution concentration of ^{90}Sr. It must be noted that because of the small amount of water used in the saturation extract, the desorbed ^{90}Sr is actually concentrated relative to ^{90}Sr levels in the adsorption isotherm experiment. The clinoptilolite indicates a greater than 90 percent reduction over NC apatite stabilization, regardless of incubation time. The bone char sorbent is also exceptional in its ability to stabilize ^{90}Sr with 90 percent reductions over NC apatite stabilization. Increasing the incubation time does not proportionately increase the stabilization factor for the bone char. Hydroxyapatite reduces ^{90}Sr solution concentration more than the NC apatite, but is distinctly inferior to the capabilities of the bone char and clinoptilolite.

To test the stability of these sorbent complexes, 5 pore volumes each of pH levels 5, 6, 7, 8, and 9 flowed through 200 g columns taken from the 1 week, 2 week, and 4 week incubated soil. The column eluent was analyzed for ^{90}Sr in solution. The data are presented in Table D-2 and graphically presented in Figure 4-9. The data are normalized against the control and represented as dissolution efficiency percent.

Both the clinoptilolite and bone char soil mixtures show excellent resistance to acidic and alkaline dissolution. It is quite surprising that little difference in eluent ^{90}Sr concentrations exists between the different incubation times. The bone char indicates a slightly better stabilizing effect at lower pH with increasing incubation time. The bone char allows approximately 10 percent dissolution of the control concentration of ^{90}Sr for the pH range of 4-9 (the control ^{90}Sr

concentration ranges from 15,489 pCi/L to 22,900 pCi/L). The clinoptilolite-^{90}Sr complex resists dissolution 3 to 5 percent less than bone char, at pH levels of 5, 6, 7, 8, and 9.

The hydroxyapatite exhibits limited ^{90}Sr stability after incubation. The 4 week incubation soil/hydroxyapatite mixture proved the most resilient to dissolution, but only retained approximately 40 percent of the control solution ^{90}Sr. The resultant pH dissolution data for the NC apatite-^{90}Sr complex was not presented in graph form as the amount of ^{90}Sr released by the varying pH solutions was greater than the control.

A general observation in this experiment is that the pH of the added groundwater solution was buffered by the soil after agitation. Whether either a mildly acidic solution at pH 5 or a basic solution was used, the pH after the groundwater was in contact for 1, 2, or 4 weeks ranged from pH 8 to 9. Therefore it would probably have been more beneficial for the interpretation of this experiment to counteract the natural buffering capacity of the soil by a buffered groundwater solution. This can be realized by adding, for instance, ammonium acetate and acetic acid to the groundwater solution. The amount of buffer should exceed the natural buffering capacity of the sediment.

Since the pH was buffered by the soil, it is not warranted to interpret the data as a function of pH in the groundwater solution.

4.7 SUMMARY OF RESULTS

The important results from each of the four experimental sections are summarized in the following sections.

4.7.1 Adsorption Isotherms

- Maximum desorption of ^{90}Sr from well 199-N-105A occurs within 72 hours. The concentration of ^{90}Sr at this time of desorption is approximately 12,000 pCi/L.

- The primary adsorption isotherm indicates that the clinoptilolite has the greatest ability to reduce ^{90}Sr solution concentration. The greatest reduction occurs at clinoptilolite values of less than 2 percent. The amount of ^{90}Sr precipitated and/or adsorbed at 2 percent added clinoptilolite is approximately 85 percent.

- The bone char is second in efficiency in reducing the ^{90}Sr concentration. All concentrations of bone char reduce ^{90}Sr concentration. However, 85 percent reduction in ^{90}Sr concentration is achieved at higher concentrations of bone char: between 10 and 20 percent. At 20 percent added bone char, the ^{90}Sr concentration is nearly the same as the reduction of ^{90}Sr caused by the addition of 2-percent clinoptilolite.

4.7.2 Kinetics of Complexation

- The clinoptilolite was most efficient in reducing the solution concentration of ^{90}Sr.
- At 10 hours, the clinoptilolite reduced the 13,683 pCi/L ^{90}Sr solution concentration by 88 percent.
- Bone char reduced the ^{90}Sr concentration by 52 percent at the tenth hour of contact.
- Both clinoptilolite and bone char illustrate a plateau after the tenth hour of contact, suggesting that maximum adsorption is occurring within the first 10 hours.

4.7.3 Loading Capacity Experiment

- The K_d values are highest for the clinoptilolite and bone char for all concentrations of the $Sr(NO_3)_2$.
- The clinoptilolite has slightly higher K_d values than bone char, ranging from 585 at low concentrations of $Sr(NO_3)_2$ to 0.41 for high concentrations of $Sr(NO_3)_2$. The bone char K_ds range from 371 at low concentrations of $Sr(NO_3)_2$ to 0.31 for high concentrations of $Sr(NO_3)_2$.

4.7.4 pH Stability Test of ^{90}Sr-Phosphate Complex

- Bone char and clinoptilolite at 5 percent additions to the soil are remarkable in reducing the solution concentration of ^{90}Sr.
- The clinoptilolite indicates a greater than 90 percent reduction in solution concentration of ^{90}Sr over NC apatite stabilization. This is the case whether at 1 week or 4 weeks of incubation time.
- The bone char sorbent is also exceptional in its ability to stabilize ^{90}Sr, with 90 percent reductions in solution concentration of ^{90}Sr over NC apatite stabilization.
- Increasing the incubation time does not proportionately increase the stabilization factor for the bone char.
- Clinoptilolite and bone char soil mixtures show excellent resistance to acidic and alkaline dissolution of the ^{90}Sr-sorbent complex.
- The bone char allows approximately 10 percent of the control concentration of ^{90}Sr for the pH range of 5 to 9 (the control ^{90}Sr concentration ranges from 15,489 pCi/L to 22,900 pCi/L).

- The clinoptilolite is slightly better than the bone char, exhibiting less than 10 percent of the control concentration of pH levels of 5, 6, 7, 8, and 9.

Figure 4-1. Desorption of Strontium-90 from N-Springs Soil, Well 199-N-105A, Using Hanford Simulated Groundwater

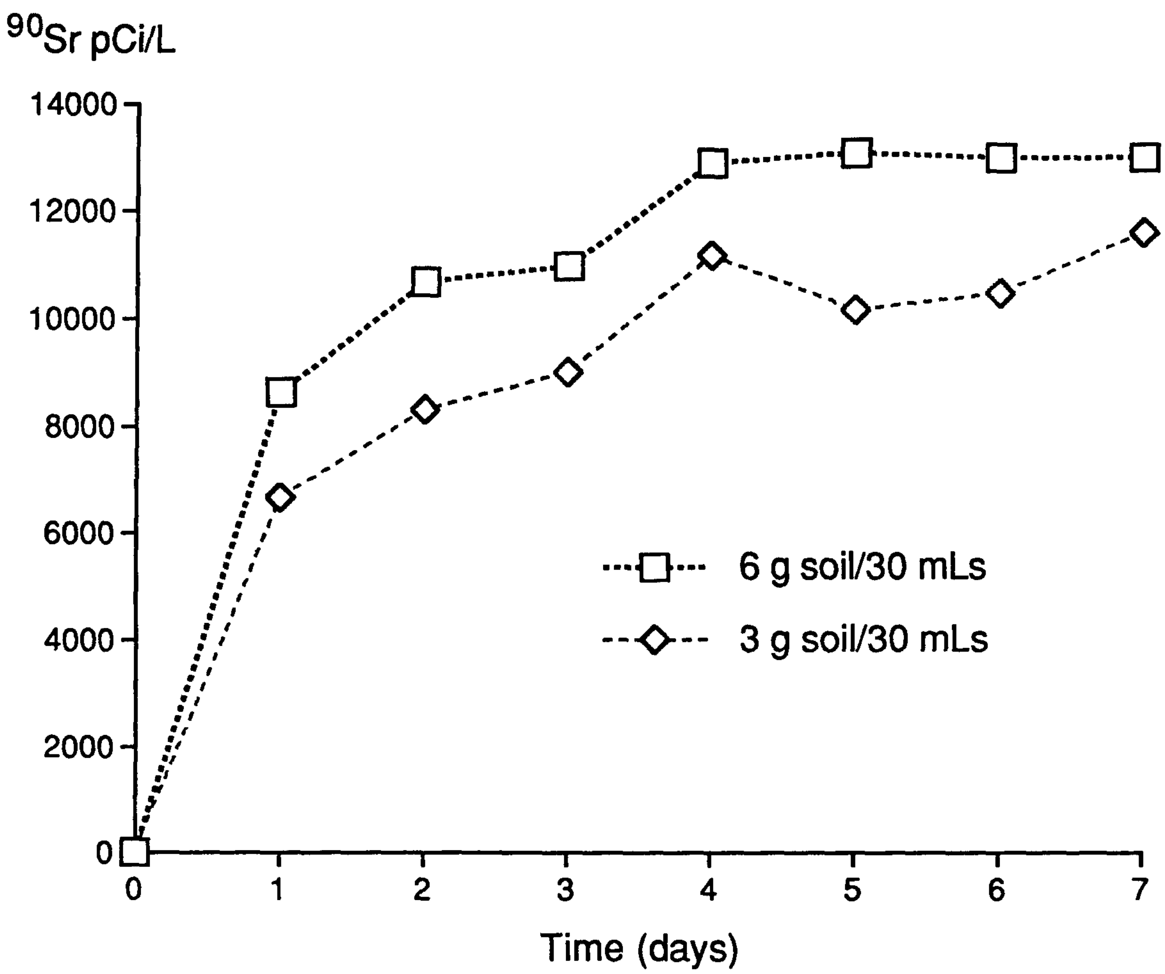


Figure 4-2. Reduction of Solution ^{90}Sr with the Addition of Incremental Amounts of Sorbent During 72 Hours Contact Time

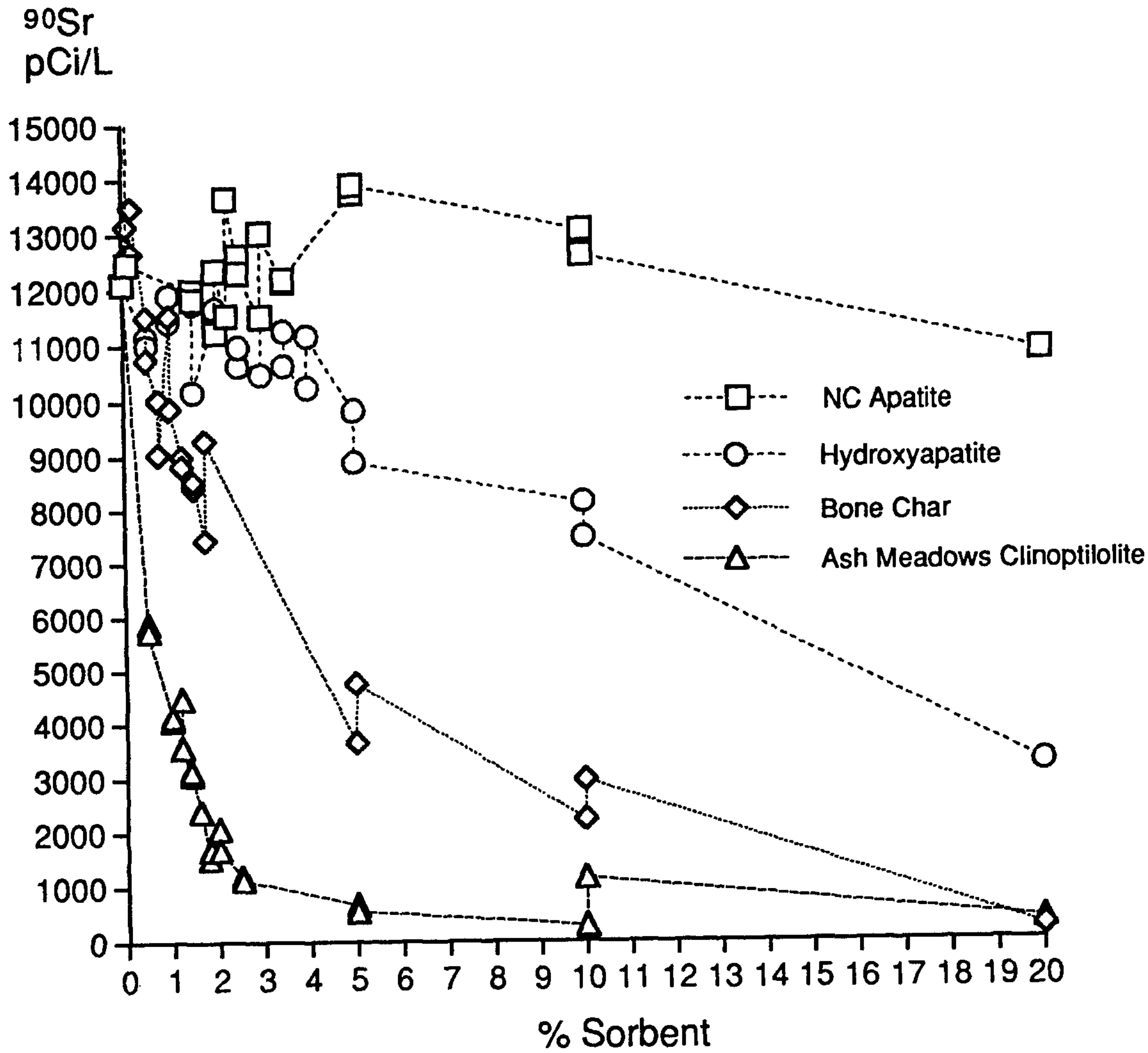


Figure 4-3. Plot of Normalized Abundances of Major Element Compositions in Contact with Various Sorbent Materials

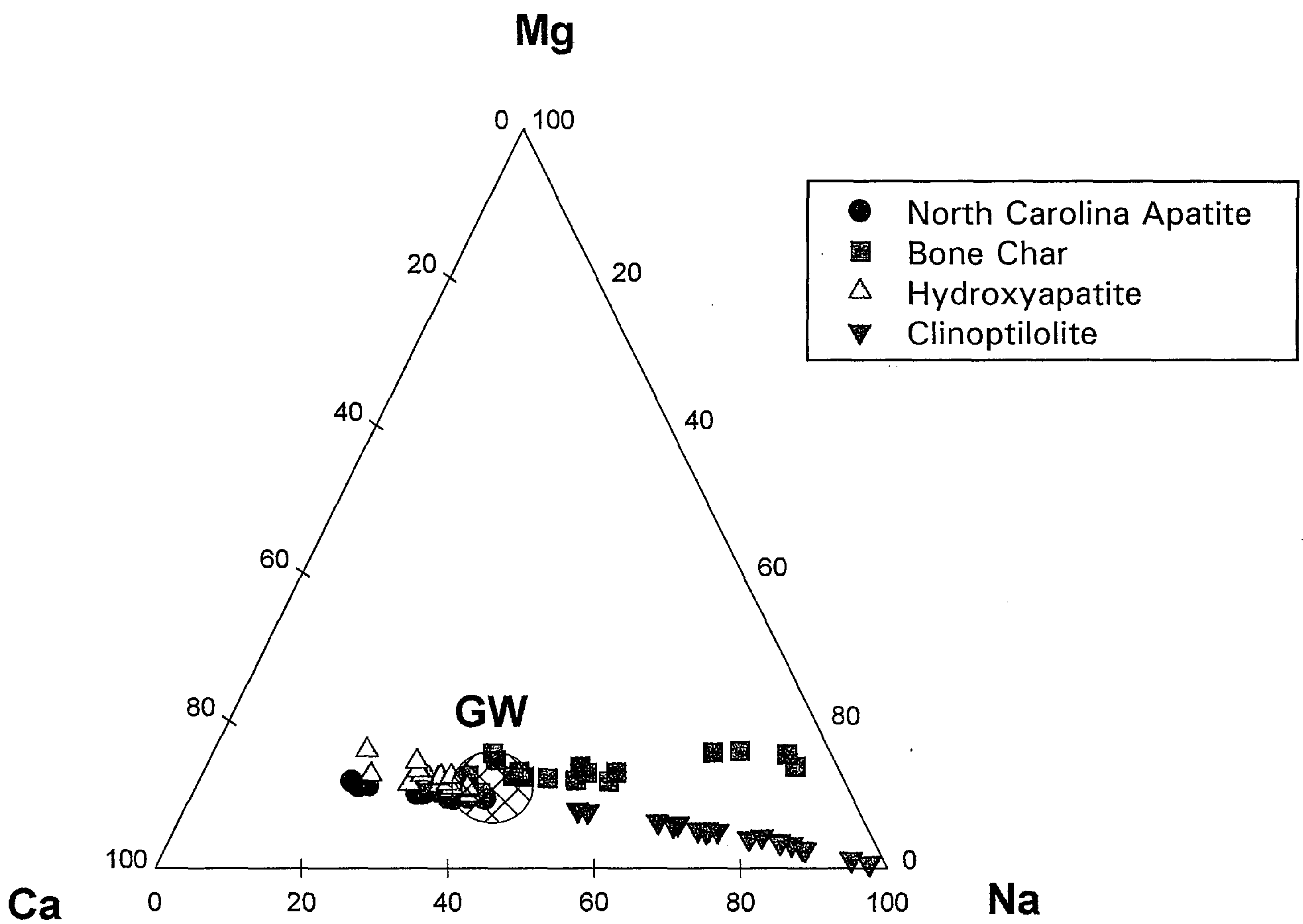


Figure 4-4. Changes in the Anion Composition of the Liquid Phase Illustrated by Normalized Element Concentrations

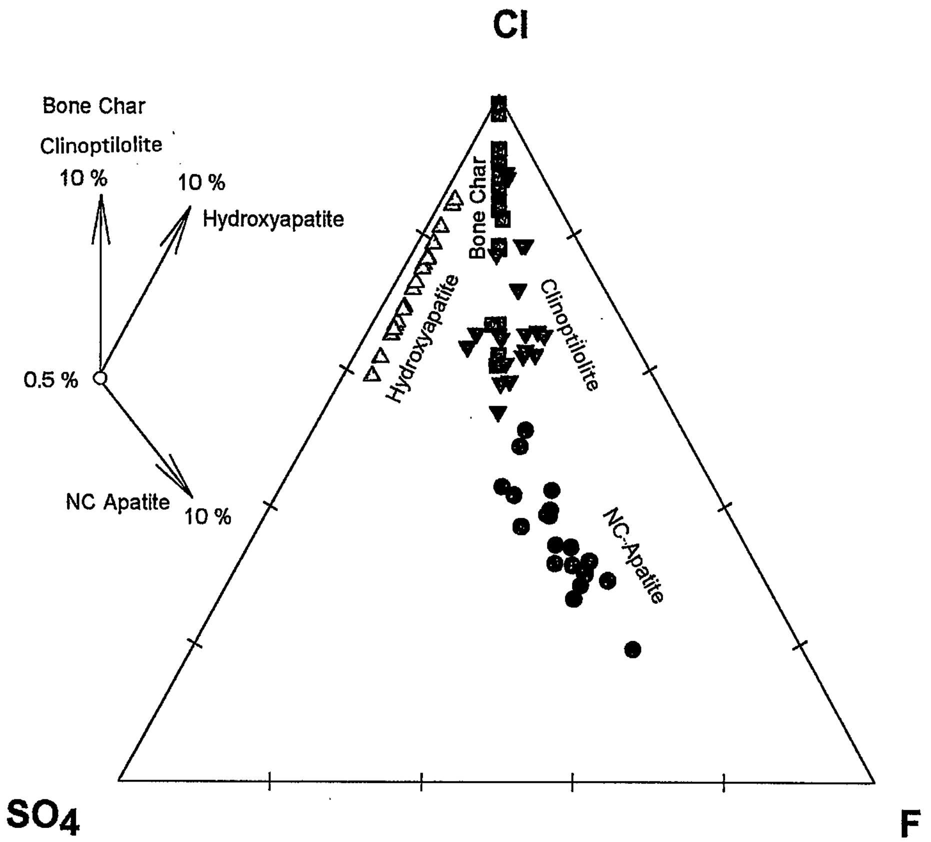


Figure 4-5. Plot of the Weight Fraction of HAP Versus the Mass Excess (Adsorbed Solute) for Alkali and Earth Alkali Elements

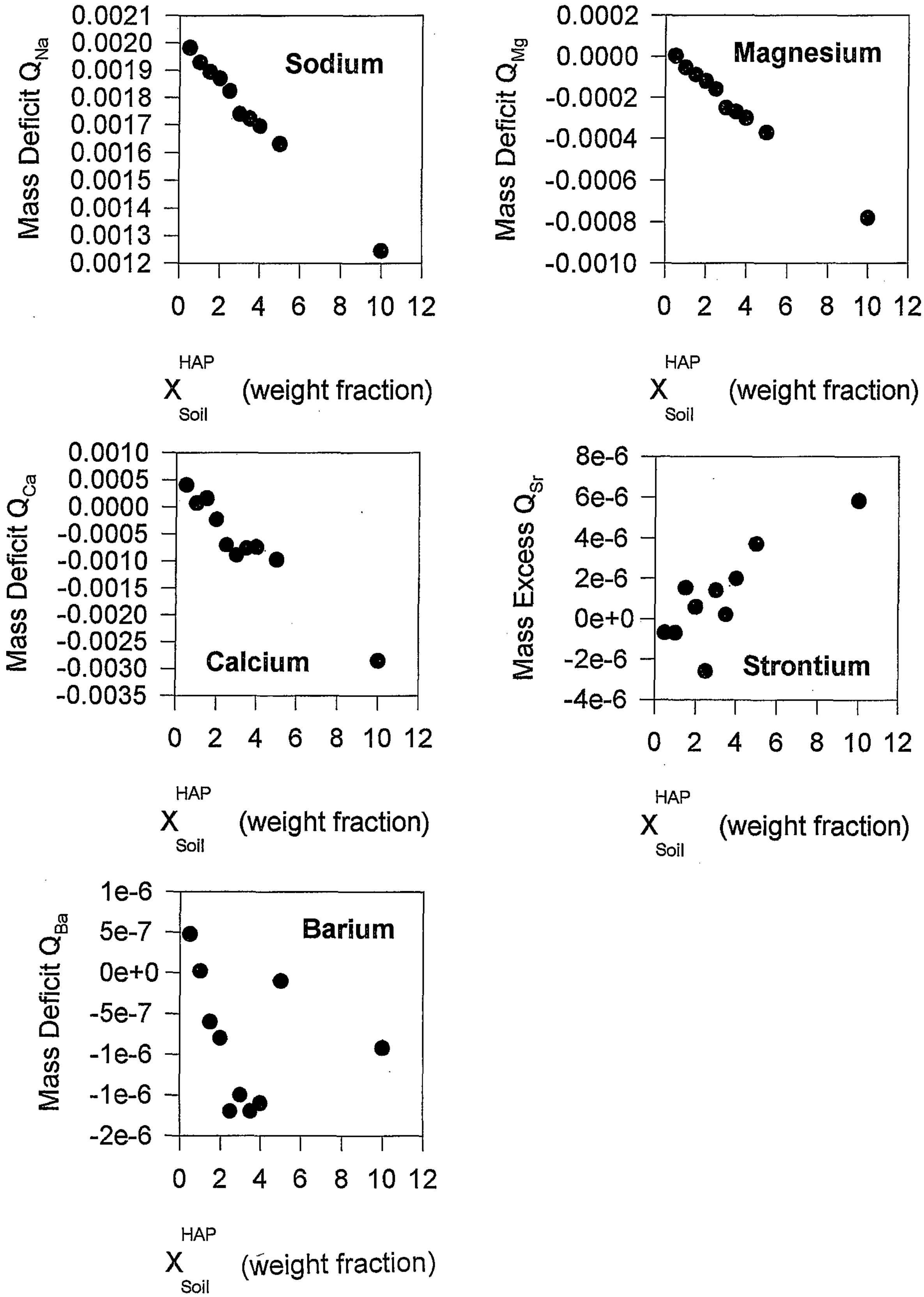


Figure 4-6. Time Required for Strontium-90 Sorption Using a 10:1 Water-to-Soil Ratio and a Fixed Amount of Sorbent Material

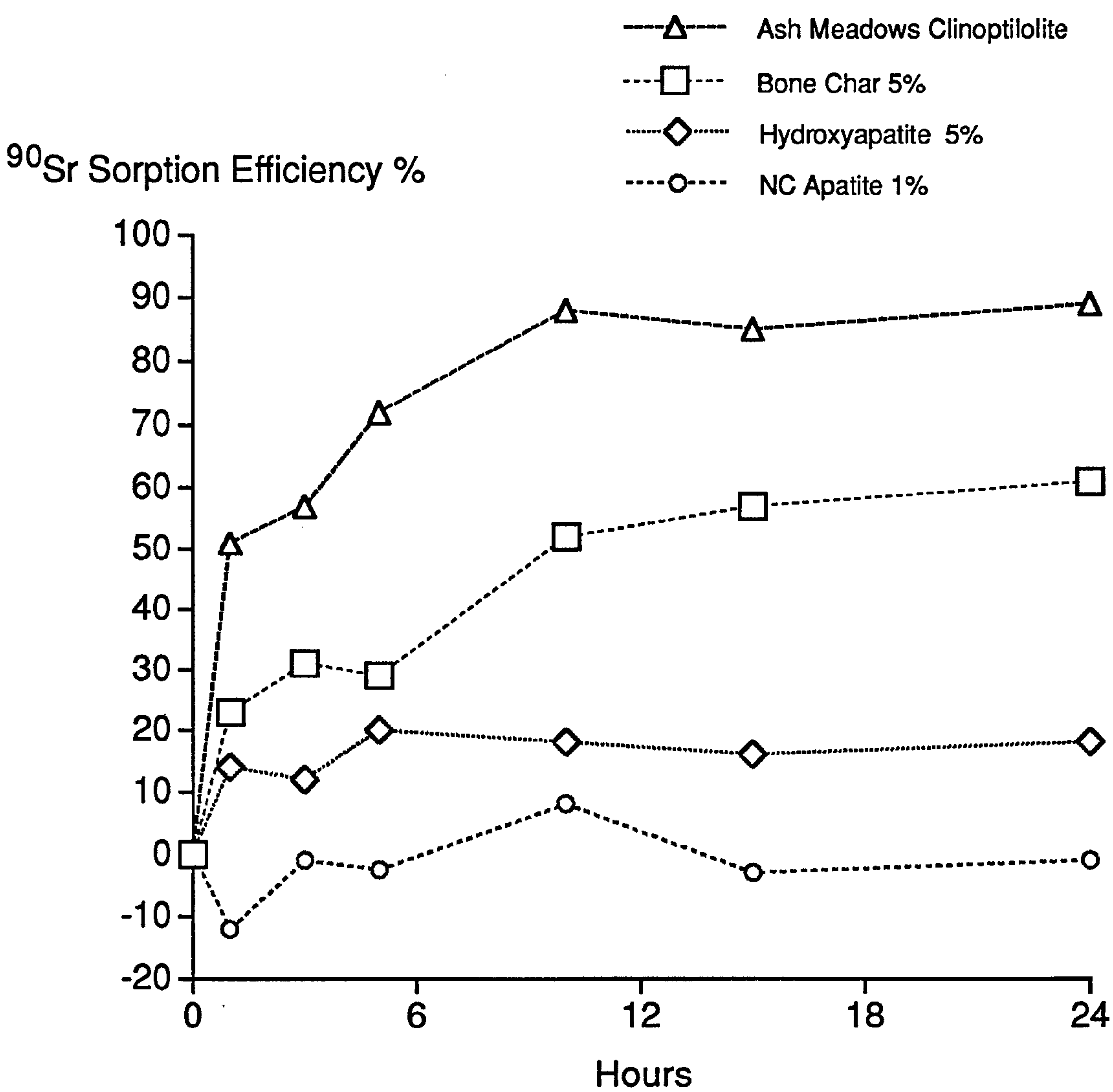


Figure 4-7. Strontium-90 Loading Capacity of the Sorbents Expressed as K_d Values

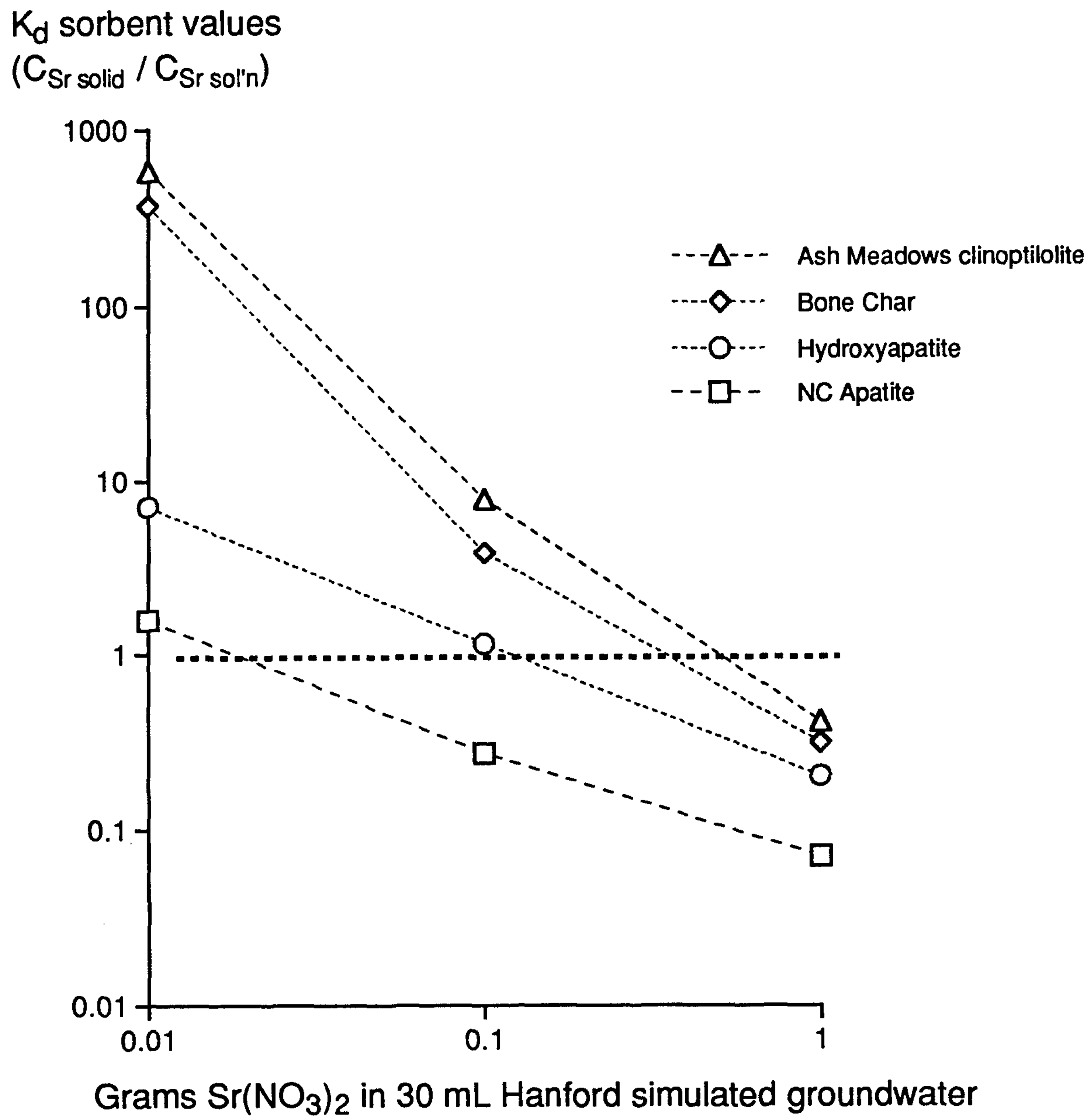


Figure 4-8. Strontium-90 in Solution After Complexed with Sorbent for 1, 2, and 4 Weeks

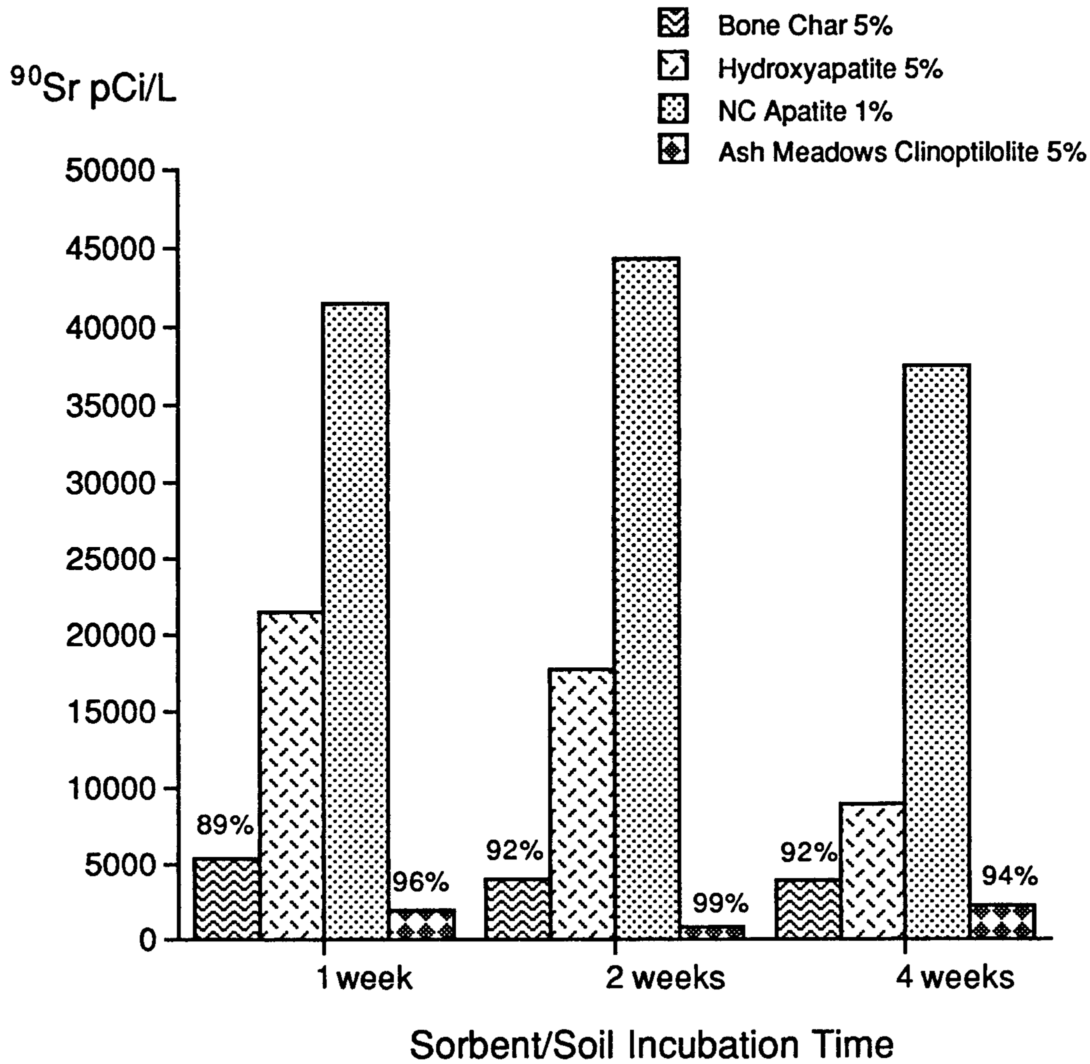
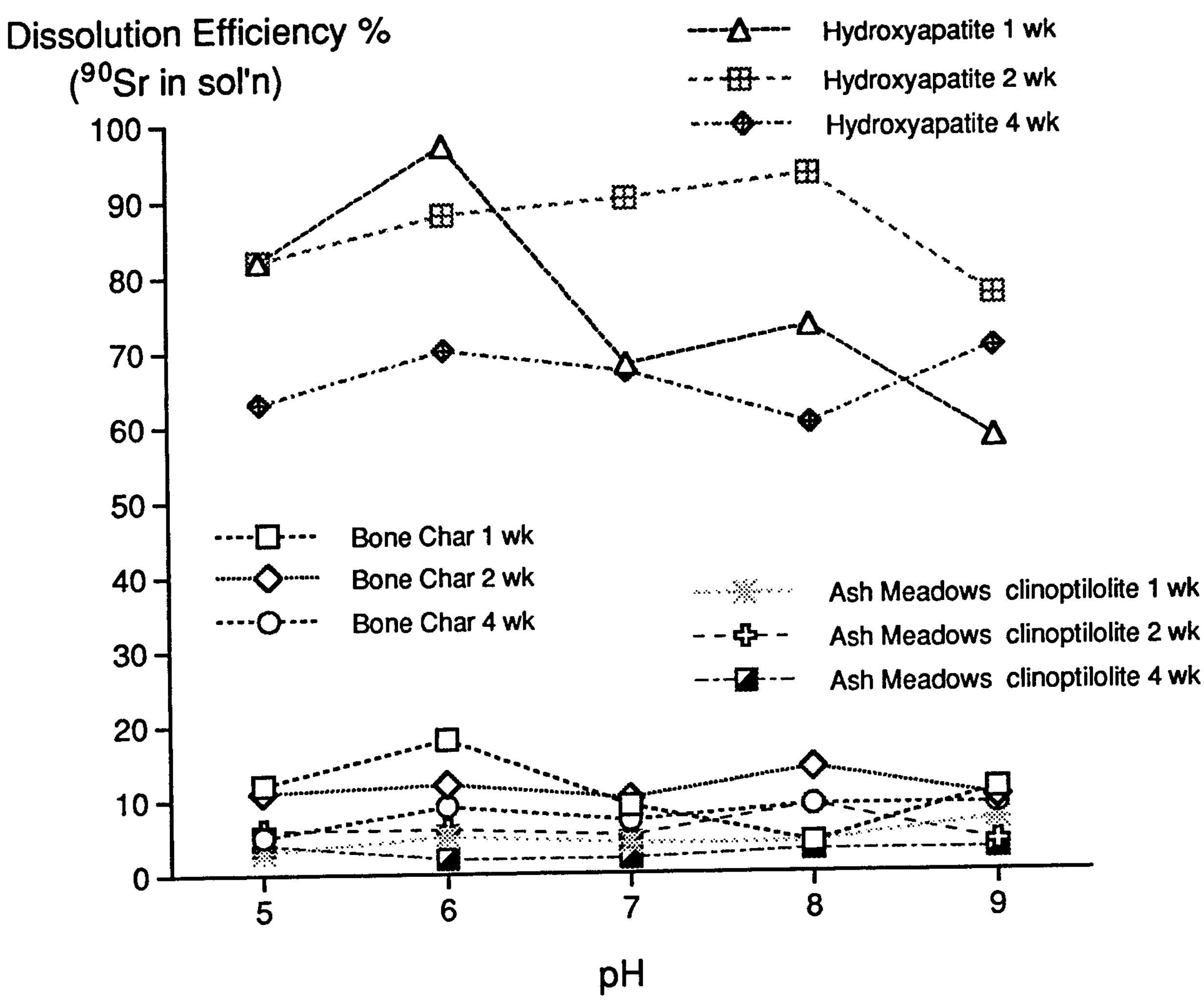


Figure 4-9. pH Stability of the Incubated 1, 2, and 4 Week ^{90}Sr-Sorbent Complexes



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APPENDIX A.

Experiment A: Primary Absorption Experiment

Table A-1. Liquid Scintillation Counting of Strontium-90, and pH and Conductivity Data from the Preliminary Desorption Experiment

	Time of desorption	Date of counting	Sr-90 Bq/mL	Sr-90 pCi/L	pH	Conductivity microSi/cm
3 g of soil	1 day	10/10/95	0.27	7,244	8.47	na
3 g of soil	1 day	10/10/95	0.23	6,099	8.44	na
3 g of soil	2 days	10/10/95	0.32	8,776	8.38	na
3 g of soil	2 days	10/10/95	0.29	7,871	8.35	na
3 g of soil	3 days	10/10/95	0.31	8,249	8.48	na
3 g of soil	3 days	10/10/95	0.36	9,809	8.38	na
3 g of soil	4 days	10/10/95	0.47	12,575	8.29	140
3 g of soil	4 days	10/10/95	0.36	9,788	8.37	147
3 g of soil	5 days	10/10/95	0.36	9,766	8.32	146
3 g of soil	5 days	10/11/95	0.39	10,596	8.33	146
3 g of soil	6 days	10/11/95	0.38	10,362	8.46	151
3 g of soil	6 days	10/11/95	0.39	10,604	8.43	150
3 g of soil	7 days	10/11/95	0.44	11,936	7.88	155
3 g of soil	7 days	10/11/95	0.42	11,284	7.96	152
6 g of soil	1 day	10/11/95	0.32	8,534	8.47	na
6 g of soil	1 day	10/11/95	0.32	8,761	8.4	na
6 g of soil	2 days	10/11/95	0.37	9,990	8.4	na
6 g of soil	2 days	10/11/95	0.42	11,403	8.29	na
6 g of soil	3 days	10/11/95	0.37	9,984	8.41	na
6 g of soil	3 days	10/11/95	0.44	11,991	8.39	na
6 g of soil	4 days	10/11/95	0.43	11,657	8.37	150
6 g of soil	4 days	10/11/95	0.52	14,147	8.37	158
6 g of soil	5 days	10/11/95	0.50	13,489	8.15	159
6 g of soil	5 days	10/11/95	0.47	12,708	8.31	162
6 g of soil	6 days	10/11/95	0.47	12,694	8.3	157
6 g of soil	6 days	10/12/95	0.49	13,308	8.42	158
6 g of soil	7 days	10/12/95	0.51	13,850	7.96	161
6 g of soil	7 days	10/12/95	0.45	12,160	7.98	157
Hanford Water		10/13/95	0	-	8.2	122

Table A-2. Ion Chromotography Data from the Preliminary Desorption Experiment

	Time of desorption	Fluoride ppm	Chloride ppm	Nitrate ppm	Phosphate ppm	Sulfate ppm
3 g of soil	1 day	na	na	na	na	na
3 g of soil	1 day	na	na	na	na	na
3 g of soil	2 days	na	na	na	na	na
3 g of soil	2 days	na	na	na	na	na
3 g of soil	3 days	na	na	na	na	na
3 g of soil	3 days	na	na	na	na	na
3 g of soil	4 days	<0.1	1.67	9.17	<0.5	18.2
3 g of soil	4 days	<0.1	1.72	8.89	3.20	18.1
3 g of soil	5 days	<0.1	1.71	9.19	<0.5	18.2
3 g of soil	5 days	<0.1	1.58	9.71	<0.5	18.3
3 g of soil	6 days	<0.1	1.68	8.93	<0.5	18.3
3 g of soil	6 days	<0.1	1.63	9.43	<0.5	18.3
3 g of soil	7 days	na	na	na	na	na
3 g of soil	7 days	na	na	na	na	na
6 g of soil	1 day	na	na	na	na	na
6 g of soil	1 day	na	na	na	na	na
6 g of soil	2 days	na	na	na	na	na
6 g of soil	2 days	na	na	na	na	na
6 g of soil	3 days	na	na	na	na	na
6 g of soil	3 days	na	na	na	na	na
6 g of soil	4 days	na	na	na	na	na
6 g of soil	4 days	<0.1	1.91	8.77	5.58	18.0
6 g of soil	5 days	<0.1	1.76	9.36	<0.5	19.0
6 g of soil	5 days	<0.1	1.65	9.35	<0.5	18.8
6 g of soil	6 days	<0.1	1.97	9.05	2.02	19.0
6 g of soil	6 days	<0.1	1.66	9.49	<0.5	18.7
6 g of soil	7 days	<0.1	1.65	9.03	<0.5	18.8
6 g of soil	7 days	<0.1	3.39	18.71	<0.5	37.4
Hanford Water		<0.1	0.35	12.17	<0.5	16.6
Maximal error of analysis in percent		4.72	4.36	1.77	0.65	1.32

Table A-3. Liquid Scintillation Counting of Strontium-90, and pH and Conductivity Data from the Preliminary Adsorption Experiment

	Time of desorption	Date of counting	Sr-90 Bq/mL	Sr-90 pCi/L	pH	Conductivity microSi/cm
Hanford Water		10/13/95	0	-	8.2	122
2 days desorption		10/10/95	0.31	8,323	8.37	na
NC Apatite	1%	10/12/95	0.33	9,042	8.02	128
	5%	10/12/95	0.39	10,522	7.98	144
	10%	10/12/95	0.39	10,478	8	160
	20%	10/12/95	0.40	10,858	8.02	181
	pure				8.15	165
Bone Char	1%	10/12/95	0.12	3,242	8.43	212
	5%	10/12/95	0.22	5,881	8.43	157
	10%	10/12/95	0.28	7,473	8.17	123
	20%	10/12/95	0.009	232	9.54	338
	pure				10.23	386
Hydroxyapatite	1%	10/12/95	0.30	7,999	8.02	128
	5%	10/12/95	0.19	5,138	8.06	147
	10%	10/12/95	0.19	5,243	8.15	172
	20%	10/13/95	0.12	3,243	8.21	195
	pure				8.19	131
Clinoptilolite	1%	10/13/95	0.19	5,238	8.15	132
	5%	10/13/95	0.062	1,671	8.24	149
	10%	10/13/95	0.009	239	8.66	190
	20%	10/13/95	0.014	377	9.17	233
	pure				8.37	181
Ca(H2PO4)2. H2O	1%	10/13/95	0.92	24,942	6.26	529
	5%	10/13/95	1.55	41,930	6.07	1894
	10%	10/13/95	1.81	48,917	4.43	2940
	20%	10/13/95	1.98	53,618	3.51	6220
	pure				2.97	6830
Phosphoric Acid	1%	10/13/95	1.32	35,657	3.86	1044
	5%	10/13/95	1.81	49,007	2.43	3040
	10%	10/13/95	2.16	58,388	2.08	5840
	20%	10/13/95	2.49	67,215	1.82	10050
	pure				3.04	204

Table A-4. Ion Chromotography Data from the Preliminary Adsorption Experiment

		Fluoride ppm	Chloride ppm	Nitrate ppm	Phosphate ppm	Sulfate ppm
Hanford Water		<0.1	0.35	12.2	<0.5	16.6
NC Apatite	1%	0.23	0.75	16.5	<0.5	39.6
	5%	0.34	0.45	8.20	<0.5	25.9
	10%	0.46	0.46	7.30	<0.5	34.7
	20%	0.53	0.50	6.76	<0.5	46.3
	pure	0.58	0.57	8.39	<0.5	50.2
Bone Char	1%	<0.1	15.2	7.75	<0.5	19.3
	5%	<0.1	7.35	9.85	<0.5	18.3
	10%	<0.1	1.66	8.98	<0.5	17.2
	20%	<0.1	3.37	8.30	<0.5	24.2
	pure	<0.1	3.50	11.6	<0.5	24.3
Hydroxyapatite	1%	<0.1	0.47	8.23	<0.5	16.8
	5%	<0.1	0.61	7.62	<0.5	15.6
	10%	<0.1	0.78	6.55	<0.5	13.7
	20%	<0.1	1.13	3.79	0.56	11.2
	pure	<0.1	1.20	6.29	0.93	10.2
Clinoptilolite	1%	<0.1	0.61	8.06	<0.5	17.3
	5%	<0.1	1.38	8.20	<0.5	18.8
	10%	<0.1	2.66	7.96	<0.5	20.5
	20%	<0.1	5.19	6.64	<0.5	23.9
	pure	<0.1	4.96	12.2	<0.5	24.9
Maximal error of analysis in percent		4.72	4.36	1.77	0.65	1.32
Ca(H2PO4)2 •H2O	1%	<0.1	1.41	6.50	na	17.0
	5%	na	na	na	na	17.4
	10%	na	na	1.55	na	17.6
	20%	na	na	na	na	17.6
	pure	na	na	na	na	na
Phosphoric Acid	1%	na	na	na	na	19.2
	5%	na	na	na	na	na
	10%	<0.1	na	na	na	79.0
	20%	na	na	na	na	na
	pure	na	na	na	na	na
Maximal error of analysis in percent		11.7	52.6	1.65	54.6	1.22

Table A-5. Liquid Scintillation Counting of Stronium-90, pH, and Conductivity Data from the Primary Adsorption Isotherm Experiment (1 of 2)

Material Tested	Percent Material Added	Date of counting	Sr-90 Bq/mL	Sr-90 pCi/L	pH	Conductivity microSi/cm
NC Apatite	0.5 %	11/27/95	0.51	13780	9.36	136
	0.5 %	11/27/95	0.45	12149	8.76	134
	1 %	11/27/95	0.88	23829	8.50	131
	1 %	11/27/95	0.46	12472	8.34	139
	1.5 %	11/27/95	0.44	11981	8.29	138
	1.5 %	11/27/95	0.44	11824	8.46	129
	2 %	11/28/95	0.42	11235	8.51	132
	2 %	11/28/95	0.46	12342	8.48	136
	2.25 %	11/28/95	0.43	11531	8.44	133
	2.25 %	11/28/95	0.51	13650	8.38	147
	2.5 %	11/28/95	0.47	12609	8.54	135
	2.5 %	11/28/95	0.46	12299	7.72	137
	3 %	11/28/95	0.43	11515	9.56	135
	3 %	11/28/95	0.48	13019	9.36	132
	3.5 %	11/28/95	0.45	12136	8.71	132
	3.5 %	11/28/95	0.45	12179	8.40	130
	5 %	11/28/95	0.51	13733	8.13	165
	5 %	11/28/95	0.51	13882	8.20	160
	10 %	11/28/95	0.48	13048	8.20	180
	10 %	11/28/95	0.47	12597	8.20	178
Bone Char	0.1 %	11/28/95	0.47	12619	6.70	152
	0.1 %	11/28/95	0.49	13152	7.98	133
	0.2 %	11/29/95	0.47	12665	8.17	133
	0.2 %	11/29/95	0.50	13487	8.14	153
	0.5 %	11/29/95	0.43	11509	8.19	142
	0.5 %	11/29/95	0.40	10750	8.55	123
	0.75 %	11/29/95	0.37	10027	8.50	126
	0.75 %	11/29/95	0.33	9044	8.46	119
	1 %	11/29/95	0.43	11529	8.45	145
	1 %	11/29/95	0.36	9863	8.52	139
	1.25 %	11/29/95	0.33	8995	8.85	129
	1.25 %	11/29/95	0.33	8822	8.96	130
	1.5 %	11/29/95	0.31	8418	9.02	131
	1.5 %	11/29/95	0.32	8539	9.08	132
	1.75 %	11/29/95	0.28	7438	9.11	135
	1.75 %	11/29/95	0.34	9288	8.71	143
	5 %	11/29/95	0.13	3643	9.33	193
	5 %	11/29/95	0.18	4745	9.27	184
	10 %	11/29/95	0.08	2216	9.55	272
	10 %	11/29/95	0.11	2953	9.42	273

Table A-5. Liquid Scintillation Counting of Stronium-90, pH, and Conductivity Data from the Primary Adsorption Isotherm Experiment (2 of 2)

Material Tested	Percent Material Added	Date of counting	Sr-90 Bq/mL	Sr-90 pCi/L	pH	Conductivity microSi/cm
Hydroxyapatite	0.5 %	11/29/95	0.41	11146	8.42	133
	0.5 %	11/29/95	0.41	10999	8.48	130
	1 %	11/29/95	0.42	11423	8.43	134
	1 %	11/29/95	0.44	11891	8.31	137
	1.5 %	11/29/95	0.43	11747	8.36	135
	1.5 %	11/29/95	0.38	10167	8.35	136
	2 %	11/29/95	0.43	11540	8.44	139
	2 %	11/29/95	0.43	11663	8.38	139
	2.5 %	11/29/95	0.39	10631	8.31	142
	2.5 %	11/29/95	0.41	10969	8.34	144
	3 %	11/29/95	0.39	10473	7.34	138
	3 %	11/29/95	0.43	11503	8.04	150
	3.5 %	11/29/95	0.42	11249	8.21	144
	3.5 %	11/29/95	0.39	10627	8.10	151
	4 %	11/29/95	0.38	10230	8.20	152
	4 %	11/29/95	0.41	11150	8.27	149
	5 %	11/29/95	0.36	9816	8.21	151
	5 %	11/29/95	0.33	8876	8.25	153
	10 %	11/29/95	0.30	8123	8.12	179
	10 %	11/29/95	0.28	7467	8.09	180
Clinoptilolite	0.5 %	11/29/95	0.22	5880	8.51	126
	0.5 %	11/29/95	0.21	5749	8.67	123
	1 %	11/29/95	0.15	4072	8.68	132
	1 %	11/29/95	0.15	4138	8.71	130
	1.2 %	11/30/95	0.17	4477	8.64	131
	1.2 %	11/30/95	0.13	3569	8.81	135
	1.4 %	11/30/95	0.11	3074	8.63	140
	1.4 %	11/30/95	0.12	3143	8.71	134
	1.6 %	11/30/95	0.09	2395	8.72	139
	1.6 %	11/30/95	not detected		8.71	135
	1.8 %	11/30/95	0.06	1527	8.89	141
	1.8 %	11/30/95	0.06	1700	8.89	137
	2 %	11/30/95	0.08	2070	8.94	142
	2 %	11/30/95	0.06	1682	8.90	132
	2.5 %	11/30/95	0.04	1202	9.12	150
	2.5 %	11/30/95	0.04	1133	9.03	148
	5 %	11/30/95	0.02	663	9.15	177
	5 %	11/30/95	0.02	550	9.22	172
	10 %	11/30/95	0.01	275	9.64	224
	10 %	11/30/95	0.04	1152	9.66	227
	Hanford Water	12/8/95	0.48	12851	8.33	129
Blank	Hanford Water				8.44	111

Table A-6a. Ion Chromotography Data from the Primary Adsorption Isotherm Experiment: North Carolina Apatite

Weight % of NC Apatite	Fluoride mg/L	Chloride mg/L	Nitrate mg/L	Phosphate mg/L	Sulfate mg/L
0.5 %	0.16 ± 0.01	0.25 ± 0.02	11.9 ± 0.27	0.53 ± 0.01	20.2 ± 0.34
0.5 %	0.13 ± 0.01	0.16 ± 0.01	11.9 ± 0.27	<0.5	20.6 ± 0.34
1 %	0.54 ± 0.04	0.23 ± 0.02	12.1 ± 0.27	<0.5	21.4 ± 0.36
1 %	0.16 ± 0.01	0.14 ± 0.01	12.2 ± 0.28	0.54 ± 0.01	21.6 ± 0.36
1.5 %	0.22 ± 0.02	0.22 ± 0.02	12.1 ± 0.27	<0.5	22.5 ± 0.38
1.5 %	0.16 ± 0.01	0.17 ± 0.01	12.4 ± 0.28	0.53 ± 0.01	22.5 ± 0.38
2 %	0.22 ± 0.02	0.16 ± 0.01	12.4 ± 0.28	<0.5	23.6 ± 0.39
2 %	0.21 ± 0.02	0.19 ± 0.01	12.9 ± 0.29	<0.5	23.4 ± 0.39
2.25 %	0.26 ± 0.02	0.18 ± 0.01	12.9 ± 0.29	<0.5	23.9 ± 0.40
2.25 %	0.23 ± 0.02	0.20 ± 0.02	12.6 ± 0.28	0.55 ± 0.01	24.1 ± 0.40
2.5 %	0.22 ± 0.02	0.14 ± 0.01	12.7 ± 0.29	<0.5	24.0 ± 0.40
2.5 %	0.23 ± 0.02	0.20 ± 0.02	21.0 ± 0.47	0.51 ± 0.01	24.9 ± 0.42
3 %	0.31 ± 0.02	0.19 ± 0.01	12.7 ± 0.29	<0.5	25.2 ± 0.42
3 %	0.31 ± 0.02	0.17 ± 0.01	15.9 ± 0.36	<0.5	25.7 ± 0.43
3.5 %	0.28 ± 0.02	0.17 ± 0.01	13.0 ± 0.29	<0.5	26.5 ± 0.44
3.5 %	0.29 ± 0.02	0.15 ± 0.01	13.3 ± 0.30	<0.5	25.8 ± 0.43
5 %	0.33 ± 0.03	0.16 ± 0.01	12.7 ± 0.29	<0.5	32.1 ± 0.54
5 %	0.35 ± 0.03	0.19 ± 0.01	12.2 ± 0.27	<0.5	29.7 ± 0.50
10 %	0.65 ± 0.05	0.18 ± 0.01	13.1 ± 0.30	<0.5	42.8 ± 0.71
10 %	0.56 ± 0.04	0.28 ± 0.02	14.1 ± 0.32	0.59 ± 0.01	39.2 ± 0.66
	mmol/L	mmol/L	mmol/L	mmol/L	mmol/L
0.5 %	8.5 ± 0.6	7.1 ± 0.5	192 ± 4	5.6 ± 0.1	210 ± 4
0.5 %	6.7 ± 0.5	4.5 ± 0.3	193 ± 4	< 5.3	214 ± 4
1 %	28.5 ± 2.1	6.5 ± 0.5	195 ± 4	< 5.3	222 ± 4
1 %	8.2 ± 0.6	4.0 ± 0.3	197 ± 4	5.7 ± 0.1	224 ± 4
1.5 %	11.7 ± 0.9	6.3 ± 0.5	195 ± 4	< 5.3	235 ± 4
1.5 %	8.2 ± 0.6	4.9 ± 0.4	200 ± 5	5.5 ± 0.1	234 ± 4
2 %	11.8 ± 0.9	4.6 ± 0.3	199 ± 4	< 5.3	245 ± 4
2 %	11.2 ± 0.8	5.3 ± 0.4	208 ± 5	< 5.3	244 ± 4
2.25 %	13.6 ± 1.0	5.0 ± 0.4	208 ± 5	< 5.3	249 ± 4
2.25 %	12.0 ± 0.9	5.8 ± 0.4	203 ± 5	5.8 ± 0.1	251 ± 4
2.5 %	11.7 ± 0.9	4.1 ± 0.3	205 ± 5	< 5.3	250 ± 4
2.5 %	12.2 ± 0.9	5.7 ± 0.4	338 ± 8	5.4 ± 0.1	259 ± 4
3 %	16.5 ± 1.2	5.2 ± 0.4	204 ± 5	< 5.3	262 ± 4
3 %	16.1 ± 1.2	4.8 ± 0.4	256 ± 6	< 5.3	268 ± 4
3.5 %	14.9 ± 1.1	4.9 ± 0.4	210 ± 5	< 5.3	276 ± 5
3.5 %	15.1 ± 1.1	4.2 ± 0.3	214 ± 5	< 5.3	269 ± 4
5 %	17.6 ± 1.3	4.6 ± 0.3	204 ± 5	< 5.3	335 ± 6
5 %	18.4 ± 1.4	5.4 ± 0.4	196 ± 4	< 5.3	309 ± 5
10 %	34.4 ± 2.6	5.2 ± 0.4	212 ± 5	< 5.3	446 ± 7
10 %	29.2 ± 2.2	7.8 ± 0.6	228 ± 5	6.2 ± 0.1	408 ± 7

Table A-6b. Ion Chromotography Data from the Primary Adsorption Isotherm Experiment: Bone Char

Weight %of Bone Char	Flouride mg/L	Chloride mg/L	Nitrate mg/L	Phosphate mg/L	Sulfate mg/L
0.1 %	0.11 ± 0.01	0.30 ± 0.02	13.8 ± 0.3	<0.5	19.4 ± 0.3
0.1 %	0.10	0.33 ± 0.02	12.5 ± 0.3	<0.5	19.6 ± 0.3
0.2 %	<0.1	0.40 ± 0.03	12.8 ± 0.3	<0.5	19.6 ± 0.3
0.2 %	0.11 ± 0.01	0.38 ± 0.03	12.9 ± 0.3	0.54 ± 0.01	19.9 ± 0.3
0.5 %	<0.1	0.72 ± 0.05	13.3 ± 0.3	<0.5	19.6 ± 0.3
0.5 %	<0.1	0.70 ± 0.05	12.5 ± 0.3	<0.5	19.3 ± 0.3
0.75 %	<0.1	1.0 ± 0.1	12.7 ± 0.3	<0.5	19.5 ± 0.3
0.75 %	0.13 ± 0.01	1.0 ± 0.1	12.7 ± 0.3	<0.5	19.6 ± 0.3
1 %	<0.1	1.2 ± 0.1	13.1 ± 0.3	0.52 ± 0.01	19.5 ± 0.3
1 %	<0.1	1.3 ± 0.1	13.5 ± 0.3	<0.5	19.5 ± 0.3
1.25 %	0.12 ± 0.01	1.7 ± 0.1	13.0 ± 0.3	<0.5	19.5 ± 0.3
1.25 %	<0.1	1.5 ± 0.1	13.0 ± 0.3	<0.5	19.6 ± 0.3
1.5 %	<0.1	1.9 ± 0.1	13.0 ± 0.3	<0.5	19.5 ± 0.3
1.5 %	<0.1	2.0 ± 0.2	13.1 ± 0.3	<0.5	19.6 ± 0.3
1.75 %	<0.1	2.4 ± 0.2	13.1 ± 0.3	<0.5	19.7 ± 0.3
1.75 %	<0.1	2.3 ± 0.2	12.9 ± 0.3	<0.5	19.7 ± 0.3
5 %	<0.1	8.4 ± 0.6	17.2 ± 0.4	<0.5	20.9 ± 0.3
5 %	<0.1	7.6 ± 0.6	13.1 ± 0.3	<0.5	20.6 ± 0.3
10 %	<0.1	16.7 ± 1.3	12.5 ± 0.3	<0.5	22.8 ± 0.4
10 %	<0.1	17.1 ± 1.3	12.6 ± 0.3	<0.5	22.8 ± 0.4
Bone Char	**mmol/L**	**mmol/L**	**mmol/L**	**mmol/L**	**mmol/L**
0.1 %	5.9 ± 0.4	8.4 ± 0.6	223 ± 5	< 5.3	202 ± 3
0.1 %	< 5.3	9.2 ± 0.7	201 ± 5	< 5.3	204 ± 3
0.2 %	< 5.3	11.2 ± 0.9	207 ± 5	< 5.3	204 ± 3
0.2 %	5.6 ± 0.4	10.8 ± 0.8	208 ± 5	5.7 ± 0.1	207 ± 3
0.5 %	< 5.3	20.3 ± 1.5	214 ± 5	< 5.3	204 ± 3
0.5 %	< 5.3	19.6 ± 1.5	201 ± 5	< 5.3	201 ± 3
0.75 %	< 5.3	28 ± 2	205 ± 5	< 5.3	203 ± 3
0.75 %	6.9 ± 0.5	27 ± 2	206 ± 5	< 5.3	204 ± 3
1 %	< 5.3	34 ± 3	212 ± 5	5.4 ± 0.1	203 ± 3
1 %	< 5.3	37 ± 3	218 ± 5	< 5.3	203 ± 3
1.25 %	6.1 ± 0.5	48 ± 4	209 ± 5	< 5.3	203 ± 3
1.25 %	< 5.3	42 ± 3	209 ± 5	< 5.3	204 ± 3
1.5 %	< 5.3	55 ± 4	209 ± 5	< 5.3	203 ± 3
1.5 %	< 5.3	56 ± 4	212 ± 5	< 5.3	204 ± 3
1.75 %	< 5.3	68 ± 5	211 ± 5	< 5.3	206 ± 3
1.75 %	< 5.3	66 ± 5	208 ± 5	< 5.3	205 ± 3
5 %	< 5.3	237 ± 18	277 ± 6	< 5.3	217 ± 4
5 %	< 5.3	215 ± 16	212 ± 5	< 5.3	214 ± 4
10 %	< 5.3	471 ± 36	201 ± 5	< 5.3	237 ± 4
10 %	< 5.3	482 ± 36	203 ± 5	< 5.3	237 ± 4

Table A-6c. Ion Chromotography Data from the Primary Adsorption Isotherm Experiment: Hydroxyapatite

Weight % of Hydroxyapatite	Flouride mg/L	Chloride mg/L	Nitrate mg/L	Phosphate mg/L	Sulfate mg/L
0.5 %	<0.1	0.18 ± 0.01	12.6 ± 0.3	<0.5	19.4 ± 0.3
0.5 %	<0.1	0.16 ± 0.01	12.8 ± 0.3	<0.5	19.4 ± 0.3
1 %	<0.1	0.17 ± 0.01	12.7 ± 0.3	0.56 ± 0.01	19.3 ± 0.3
1 %	<0.1	0.21 ± 0.02	12.5 ± 0.3	0.59 ± 0.01	19.3 ± 0.3
1.5 %	<0.1	0.21 ± 0.02	12.2 ± 0.3	<0.5	18.8 ± 0.3
1.5 %	<0.1	0.20 ± 0.01	12.4 ± 0.3	<0.5	19.1 ± 0.3
2 %	<0.1	0.20 ± 0.02	12.3 ± 0.3	0.56 ± 0.01	19.1 ± 0.3
2 %	<0.1	0.33 ± 0.02	12.4 ± 0.3	0.55 ± 0.01	19.0 ± 0.3
2.5 %	<0.1	0.24 ± 0.02	12.1 ± 0.3	<0.5	18.8 ± 0.3
2.5 %	<0.1	0.23 ± 0.02	12.1 ± 0.3	0.53 ± 0.01	18.7 ± 0.3
3 %	<0.1	0.28 ± 0.02	11.8 ± 0.3	0.53 ± 0.01	18.5 ± 0.3
3 %	<0.1	0.38 ± 0.03	11.7 ± 0.3	<0.5	18.5 ± 0.3
3.5 %	<0.1	0.26 ± 0.02	11.7 ± 0.3	<0.5	18.4 ± 0.3
3.5 %	<0.1	0.28 ± 0.02	11.5 ± 0.3	0.54 ± 0.01	18.4 ± 0.3
4 %	<0.1	0.31 ± 0.02	11.6 ± 0.3	0.56 ± 0.01	18.3 ± 0.3
4 %	<0.1	0.44 ± 0.03	11.8 ± 0.3	0.56 ± 0.01	18.7 ± 0.3
5 %	<0.1	0.33 ± 0.02	11.2 ± 0.3	0.56 ± 0.01	17.8 ± 0.3
5 %	<0.1	0.32 ± 0.02	11.2 ± 0.3	0.56 ± 0.01	17.5 ± 0.3
10 %	<0.1	0.49 ± 0.04	10.0 ± 0.2	0.57 ± 0.01	16.1 ± 0.3
10 %	<0.1	0.50 ± 0.04	9.7 ± 0.2	0.59 ± 0.01	15.7 ± 0.3
	mmol/L	mmol/L	mmol/L	mmol/L	mmol/L
0.5 %	< 5.3	5.1 ± 0.4	203 ± 5	< 5.3	202 ± 3
0.5 %	< 5.3	4.4 ± 0.3	206 ± 5	< 5.3	202 ± 3
1 %	< 5.3	4.9 ± 0.4	205 ± 5	5.9 ± 0.1	201 ± 3
1 %	< 5.3	6.1 ± 0.5	201 ± 5	6.2 ± 0.1	201 ± 3
1.5 %	< 5.3	6.0 ± 0.5	198 ± 4	< 5.3	195 ± 3
1.5 %	< 5.3	5.6 ± 0.4	200 ± 5	< 5.3	199 ± 3
2 %	< 5.3	5.8 ± 0.4	198 ± 4	5.9 ± 0.1	198 ± 3
2 %	< 5.3	9.3 ± 0.7	200 ± 5	5.8 ± 0.1	198 ± 3
2.5 %	< 5.3	6.7 ± 0.5	195 ± 4	< 5.3	196 ± 3
2.5 %	< 5.3	6.5 ± 0.5	196 ± 4	5.5 ± 0.1	195 ± 3
3 %	< 5.3	7.9 ± 0.6	190 ± 4	5.6 ± 0.1	193 ± 3
3 %	< 5.3	10.7 ± 0.8	189 ± 4	< 5.3	193 ± 3
3.5 %	< 5.3	7.4 ± 0.6	189 ± 4	< 5.3	192 ± 3
3.5 %	< 5.3	7.8 ± 0.6	185 ± 4	5.7 ± 0.1	191 ± 3
4 %	< 5.3	8.6 ± 0.7	187 ± 4	5.9 ± 0.1	191 ± 3
4 %	< 5.3	12.5 ± 0.9	191 ± 4	5.9 ± 0.1	195 ± 3
5 %	< 5.3	9.3 ± 0.7	181 ± 4	5.8 ± 0.1	186 ± 3
5 %	< 5.3	9.0 ± 0.7	180 ± 4	5.9 ± 0.1	182 ± 3
10 %	< 5.3	13.7 ± 1.0	161 ± 4	6.0 ± 0.1	168 ± 3
10 %	< 5.3	14.2 ± 1.1	156 ± 4	6.2 ± 0.1	163 ± 3

Table A-6d. Ion Chromotography Data from the Primary Adsorption Isotherm Experiment: Clinoptilolite

Weight % of clinoptilolite	Flouride mg/L	Chloride mg/L	Nitrate mg/L	Phosphate mg/L	Sulfate mg/L
0.5 %	0.12 ± 0.01	0.28 ± 0.02	12.4 ± 0.3	<0.5	19.8 ± 0.3
0.5 %	<0.1	0.23 ± 0.02	12.2 ± 0.3	<0.5	19.8 ± 0.3
1 %	0.13 ± 0.01	0.33 ± 0.03	12.5 ± 0.3	<0.5	20.0 ± 0.3
1 %	0.07 ± 0.01	0.29 ± 0.02	12.6 ± 0.3	<0.5	20.0 ± 0.3
1.2 %	0.14 ± 0.01	0.31 ± 0.02	12.6 ± 0.3	<0.5	20.3 ± 0.3
1.2 %	0.08 ± 0.01	0.33 ± 0.02	12.6 ± 0.3	<0.5	20.1 ± 0.3
1.4 %	0.13 ± 0.01	0.40 ± 0.03	12.5 ± 0.3	<0.5	21.1 ± 0.4
1.4 %	0.13 ± 0.01	0.39 ± 0.03	12.9 ± 0.3	<0.5	20.6 ± 0.3
1.6 %	0.17 ± 0.01	0.41 ± 0.03	12.8 ± 0.3	<0.5	20.5 ± 0.3
1.6 %	0.21 ± 0.02	0.46 ± 0.04	12.3 ± 0.3	<0.5	20.6 ± 0.3
1.8 %	0.23 ± 0.02	0.57 ± 0.04	12.5 ± 0.3	<0.5	20.6 ± 0.3
1.8 %	0.11 ± 0.01	0.68 ± 0.05	12.5 ± 0.3	<0.5	20.4 ± 0.3
2 %	0.19 ± 0.01	0.49 ± 0.04	12.9 ± 0.3	0.54 ± 0.01	20.5 ± 0.3
2 %	0.19 ± 0.01	0.46 ± 0.03	12.5 ± 0.3	14.39 ± 0.26	21.9 ± 0.4
2.5 %	0.18 ± 0.01	0.67 ± 0.05	12.6 ± 0.3	1.48 ± 0.03	20.9 ± 0.3
2.5 %	0.26 ± 0.02	0.61 ± 0.05	12.8 ± 0.3	1.55 ± 0.03	21.2 ± 0.4
5 %	0.26 ± 0.02	1.21 ± 0.09	13.1 ± 0.3	1.01 ± 0.02	21.9 ± 0.4
5 %	0.23 ± 0.02	1.11 ± 0.08	12.8 ± 0.3	0.70 ± 0.01	21.5 ± 0.4
10 %	0.21 ± 0.02	2.20 ± 0.17	13.4 ± 0.3	0.83 ± 0.02	23.1 ± 0.4
10 %	0.20 ± 0.01	2.29 ± 0.17	13.7 ± 0.3	0.90 ± 0.02	23.4 ± 0.4
	mmol/L	mmol/L	mmol/L	mmol/L	mmol/L
0.5 %	6.4 ± 0.5	7.9 ± 0.6	201 ± 5	< 5.3	206 ± 3
0.5 %	< 5.3	6.6 ± 0.5	197 ± 4	< 5.3	206 ± 3
1 %	6.9 ± 0.5	9.4 ± 0.7	202 ± 5	< 5.3	208 ± 3
1 %	3.9 ± 0.3	8.1 ± 0.6	203 ± 5	< 5.3	208 ± 3
1.2 %	7.3 ± 0.5	8.7 ± 0.7	204 ± 5	< 5.3	211 ± 4
1.2 %	4.4 ± 0.3	9.2 ± 0.7	204 ± 5	< 5.3	209 ± 3
1.4 %	6.6 ± 0.5	11.3 ± 0.9	202 ± 5	< 5.3	219 ± 4
1.4 %	6.7 ± 0.5	11.0 ± 0.8	208 ± 5	< 5.3	215 ± 4
1.6 %	9.0 ± 0.7	11.5 ± 0.9	206 ± 5	< 5.3	213 ± 4
1.6 %	10.9 ± 0.8	13.1 ± 1.0	199 ± 4	< 5.3	215 ± 4
1.8 %	12.1 ± 0.9	16.1 ± 1.2	202 ± 5	< 5.3	214 ± 4
1.8 %	6.0 ± 0.5	19.0 ± 1.4	202 ± 5	< 5.3	212 ± 4
2 %	9.8 ± 0.7	13.9 ± 1.0	208 ± 5	5.7 ± 0.1	214 ± 4
2 %	10.1 ± 0.8	13.0 ± 1.0	202 ± 5	151.6 ± 2.7	228 ± 4
2.5 %	9.5 ± 0.7	18.8 ± 1.4	203 ± 5	15.5 ± 0.3	218 ± 4
2.5 %	13.7 ± 1.0	17.3 ± 1.3	207 ± 5	16.3 ± 0.3	221 ± 4
5 %	13.6 ± 1.0	34.1 ± 2.6	211 ± 5	10.6 ± 0.2	228 ± 4
5 %	12.1 ± 0.9	31.2 ± 2.4	206 ± 5	7.3 ± 0.1	224 ± 4
10 %	11.0 ± 0.8	62.1 ± 4.7	216 ± 5	8.7 ± 0.2	241 ± 4
10 %	10.4 ± 0.8	64.6 ± 4.9	221 ± 5	9.5 ± 0.2	244 ± 4

Table A-6e. Ion Chromotography Data from the Primary Adsorption Isotherm Experiment: Hanford Soil

Soil without sorbent	Flouride mg/L	Chloride mg/L	Nitrate mg/L	Phosphate mg/L	Sulfate mg/L
100 %	0.13 ± 0.01	0.10	12.8 ± 0.5	0.7 ± 0.01	19.8 ± 0.6
100 %	0.10 ± 0.01	<0.1	13.1 ± 0.5	0.7 ± 0.01	19.9 ± 0.6
100 %	0.13 ± 0.01	<0.1	13.2 ± 0.5	<0.5	19.9 ± 0.6
100 %	0.11 ± 0.01	<0.1	13.1 ± 0.5	0.6 ± 0.01	20.0 ± 0.6
100 %	<0.1	<0.1	12.8 ± 0.5	<0.5	19.5 ± 0.6
	mmol/L	**mmol/L**	**mmol/L**	**mmol/L**	**mmol/L**
100 %	6.6 ± 0.4	<2.8	207 ± 8	7.4 ± 0.1	206 ± 7
100 %	5.5 ± 0.3	<2.8	211 ± 8	7.1 ± 0.1	208 ± 7
100 %	6.7 ± 0.4	<2.8	213 ± 8	<5.3	207 ± 7
100 %	5.9 ± 0.3	<2.8	211 ± 8	6.3 ± 0.1	208 ± 7
100 %	< 5.3	<2.8	206 ± 8	<5.3	203 ± 6

Table A-7a. Atomic Absorption Spectrophotometry Data from the Primary Adsorption Isotherm Experiment: NC Apatite

Weight % of	Sodium		Magnesium		Calcium	
NC Apatite	mg/L	StD%	mg/L	StD%	mg/L	StD%
0.5 %	7.1 ± 0.7	9.8	4.0 ± 0.02	0.5	22.8 ± 0.3	1.5
0.5 %	15.6 ± 0.2	1.2	3.7 ± 0.03	0.8	19.6 ± 0.4	2.1
1 %	13.7 ± 0.2	1.5	3.8 ± 0.001	0.03	19.8 ± 0.1	0.5
1 %	15.3 ± 0.2	1.5	4.0 ± 0.03	0.8	23.1 ± 0.3	1.1
1.5 %	14.4 ± 0.2	1.1	3.9 ± 0.01	0.2	22.5 ± 0.3	1.5
1.5 %	14.0 ± 0.3	1.9	3.7 ± 0.02	0.5	20.2 ± 0.7	3.5
2 %	13.6 ± 0.1	0.8	3.7 ± 0.01	0.4	19.7 ± 1.5	7.5
2 %	12.6 ± 0.3	2.5	3.9 ± 0.01	0.3	20.6 ± 0.5	2.7
2.25 %	14.7 ± 0.3	2.3	3.7 ± 0.01	0.2	20.3 ± 0.8	4.0
2.25 %	8.6 ± 1.6	18.2	4.1 ± 0.03	0.8	23.9 ± 0.3	1.4
2.5 %	16.4 ± 0.8	5.1	3.8 ± 0.03	0.8	20.4 ± 0.6	3.0
2.5 %	11.8 ± 0.0	0.0	3.8 ± 0.03	0.7	19.7 ± 1.9	9.4
3 %	13.5 ± 0.4	2.9	3.7 ± 0.02	0.6	19.1 ± 1.8	9.5
3 %	11.8 ± 0.4	3.8	3.7 ± 0.02	0.5	20.0 ± 2.2	10.8
3.5 %	13.1 ± 0.7	5.7	3.9 ± 0.04	1.2	20.8 ± 1.9	8.9
3.5 %	13.6 ± 0.7	5.4	3.8 ± 0.04	1.1	21.2 ± 3.0	14.3
5 %	13.3 ± 0.3	2.1	4.4 ± 0.03	0.7	25.7 ± 1.1	4.3
5 %	13.4 ± 0.1	0.7	4.3 ± 0.05	1.3	24.8 ± 1.0	4.1
10 %	14.6 ± 0.5	3.2	4.8 ± 0.02	0.5	27.7 ± 1.1	3.9
10 %	9.4 ± 0.5	5.6	4.7 ± 0.01	0.2	28.2 ± 1.2	4.3
NC Apatite	mmol/L	StD%	mmol/L	StD%	mmol/L	StD%
0.5 %	310 ± 30	9.8	165 ± 1	0.5	568 ± 8	1.5
0.5 %	679 ± 8	1.2	151 ± 1	0.8	488 ± 10	2.1
1 %	598 ± 9	1.5	155 ± 0	0.03	494 ± 2	0.5
1 %	667 ± 10	1.5	163 ± 1	0.8	576 ± 6	1.1
1.5 %	626 ± 7	1.1	162 ± 0	0.2	562 ± 9	1.5
1.5 %	609 ± 12	1.9	153 ± 1	0.5	503 ± 18	3.5
2 %	590 ± 5	0.8	153 ± 1	0.4	492 ± 37	7.5
2 %	546 ± 14	2.5	159 ± 0	0.3	514 ± 14	2.7
2.25 %	639 ± 15	2.3	154 ± 0	0.2	506 ± 20	4.0
2.25 %	373 ± 68	18.2	168 ± 1	0.8	597 ± 9	1.4
2.5 %	715 ± 36	5.1	155 ± 1	0.8	510 ± 15	3.0
2.5 %	513 ± 0	0.0	155 ± 1	0.7	490 ± 46	9.4
3 %	589 ± 17	2.9	152 ± 1	0.6	477 ± 45	9.5
3 %	514 ± 19	3.8	152 ± 1	0.5	500 ± 54	10.8
3.5 %	570 ± 33	5.7	159 ± 2	1.2	518 ± 46	8.9
3.5 %	590 ± 32	5.4	156 ± 2	1.1	528 ± 76	14.3
5 %	579 ± 12	2.1	183 ± 1	0.7	641 ± 28	4.3
5 %	583 ± 4	0.7	177 ± 2	1.3	620 ± 25	4.1
10 %	634 ± 20	3.2	196 ± 1	0.5	692 ± 27	3.9
10 %	407 ± 23	5.6	194 ± 0	0.2	704 ± 30	4.3

Table A-7b. Atomic Absorption Spectrophotometry Data from the Primary Adsorption Isotherm Experiment: Bone Char

Weight % of Bone char	Sodium mg/L	StD%	Magnesium mg/L	StD%	Calcium mg/L	StD%
0.1 %	15.0 ± 0.1	0.9	3.9 ± 0.01	0.2	19.2 ± 2.0	10.5
0.1 %	11.4 ± 0.2	1.6	4.0 ± 0.04	1.0	20.3 ± 2.0	9.8
0.2 %	14.2 ± 1.7	11.7	4.0 ± 0.001	0.03	19.6 ± 1.1	5.6
0.2 %	15.9 ± 0.1	0.8	4.6 ± 0.07	1.5	22.8 ± 1.1	4.7
0.5 %	13.7 ± 0.2	1.2	4.7 ± 0.06	1.3	19.1 ± 0.0	0.1
0.5 %	13.6 ± 1.2	9.1	4.0 ± 0.02	0.6	14.3 ± 0.3	2.1
0.75 %	14.7 ± 0.2	1.1	4.1 ± 0.05	1.1	14.4 ± 0.1	0.7
0.75 %	16.3 ± 0.5	3.1	4.2 ± 0.09	2.2	13.8 ± 0.4	2.8
1 %	16.9 ± 0.1	0.7	5.1 ± 0.03	0.7	17.1 ± 0.2	1.0
1 %	13.1 ± 1.2	8.9	4.9 ± 0.06	1.3	15.4 ± 0.2	1.1
1.25 %	11.1 ± 0.8	6.9	4.5 ± 0.06	1.4	13.3 ± 0.03	0.3
1.25 %	18.6 ± 0.1	0.3	4.3 ± 0.04	0.9	13.2 ± 0.2	1.8
1.5 %	21.5 ± 0.8	3.5	4.5 ± 0.01	0.3	12.3 ± 0.03	0.3
1.5 %	18.3 ± 0.7	4.0	4.5 ± 0.01	0.3	12.0 ± 0.6	4.7
1.75 %	20.4 ± 1.1	5.2	4.7 ± 0.01	0.2	11.0 ± 1.0	8.7
1.75 %	19.0 ± 0.7	3.6	5.1 ± 0.03	0.7	13.0 ± 1.4	10.7
5 %	34.5 ± 0.7	1.9	7.6 ± 0.02	0.3	5.8 ± 0.7	12.1
5 %	30.1 ± 0.3	0.9	6.9 ± 0.001	0.02	7.0 ± 0.7	9.7
10 %	53.4 ± 0.8	1.5	9.1 ± 0.01	0.1	3.8 ± 0.4	10.3
10 %	48.9 ± 0.9	1.8	9.6 ± 0.01	0.1	3.7 ± 0.3	7.4
Bone Char	**mmol/L**	**StD%**	**mmol/L**	**StD%**	**mmol/L**	**StD%**
0.1 %	651 ± 6	0.9	160 ± 0	0.2	479 ± 50	10.5
0.1 %	498 ± 8	1.6	163 ± 2	1.0	507 ± 49	9.8
0.2 %	619 ± 72	11.7	166 ± 0	0.03	488 ± 27	5.6
0.2 %	690 ± 6	0.8	187 ± 3	1.5	569 ± 27	4.7
0.5 %	596 ± 7	1.2	195 ± 3	1.3	477 ± 0	0.1
0.5 %	591 ± 54	9.1	165 ± 1	0.6	356 ± 7	2.1
0.75 %	639 ± 7	1.1	170 ± 2	1.1	360 ± 2	0.7
0.75 %	710 ± 22	3.1	174 ± 4	2.2	345 ± 10	2.8
1 %	736 ± 5	0.7	208 ± 1	0.7	427 ± 4	1.0
1 %	568 ± 50	8.9	200 ± 3	1.3	385 ± 4	1.1
1.25 %	485 ± 34	6.9	186 ± 3	1.4	331 ± 1	0.3
1.25 %	808 ± 3	0.3	178 ± 2	0.9	330 ± 6	1.8
1.5 %	934 ± 33	3.5	185 ± 1	0.3	307 ± 1	0.3
1.5 %	796 ± 31	4.0	186 ± 0	0.3	299 ± 14	4.7
1.75 %	889 ± 46	5.2	194 ± 0	0.2	275 ± 24	8.7
1.75 %	828 ± 29	3.6	209 ± 1	0.7	325 ± 35	10.7
5 %	1502 ± 29	1.9	314 ± 1	0.3	144 ± 17	12.1
5 %	1311 ± 12	0.9	283 ± 0	0.02	174 ± 17	9.7
10 %	2323 ± 36	1.5	376 ± 0	0.1	94 ± 10	10.3
10 %	2127 ± 38	1.8	397 ± 0	0.1	93 ± 7	7.4

Table A-7c. Atomic Absorption Spectrophotometry Data from the Primary Adsorption Isotherm Experiment: Hydroxyapatite

Weight % of Hydroxypatite	Sodium mg/L			StD%	Magnesium mg/L			StD%	Calcium mg/L			StD%
0.5 %	12.6	±	0.9	7.3	3.8	±	0.04	1.0	19.6	±	0.3	1.4
0.5 %	13.8	±	0.2	1.3	3.6	±	0.01	0.3	18.9	±	0.4	2.1
1 %	14.1	±	0.9	6.5	4.0	±	0.02	0.4	19.7	±	0.7	3.7
1 %	9.9	±	0.5	5.0	3.9	±	0.03	0.9	20.4	±	1.0	4.8
1.5 %	14.0	±	0.3	1.8	4.0	±	0.02	0.6	19.6	±	2.0	10.1
1.5 %	14.4	±	0.5	3.1	4.2	±	0.00	0.1	20.1	±	1.4	6.8
2 %	13.0	±	0.6	4.6	4.2	±	0.001	0.03	20.8	±	1.0	5.0
2 %	12.4	±	0.1	0.9	4.2	±	0.000	0.01	20.8	±	0.8	3.9
2.5 %	14.1	±	0.2	1.7	4.4	±	0.03	0.6	21.7	±	0.5	2.3
2.5 %	8.0	±	0.2	2.6	4.4	±	0.05	1.2	22.2	±	0.8	3.6
3 %	14.3	±	0.2	1.7	4.8	±	0.08	1.7	22.2	±	1.0	4.5
3 %	14.3	±	0.2	1.7	4.8	±	0.06	1.2	22.7	±	0.1	0.3
3.5 %	12.2	±	0.2	1.9	4.8	±	0.03	0.7	22.1	±	0.8	3.7
3.5 %	13.1	±	0.9	7.1	4.9	±	0.08	1.7	22.2	±	1.8	7.9
4 %	13.2	±	0.1	0.9	5.0	±	0.04	0.7	22.0	±	2.0	9.1
4 %	11.7	±	0.1	1.1	4.9	±	0.01	0.2	22.2	±	1.4	6.3
5 %	14.3	±	0.2	1.7	5.2	±	0.04	0.7	22.3	±	1.3	5.6
5 %	11.7	±	0.2	1.9	5.3	±	0.04	0.8	23.0	±	1.2	5.2
10 %	13.8	±	0.1	0.8	7.0	±	0.04	0.5	27.6	±	1.4	4.9
10 %	9.0	±	0.2	2.0	6.9	±	0.07	1.0	27.1	±	1.7	6.2
Hydroxyapatite	**mmol/L**			**StD%**	**mmol/L**			**StD%**	**mmol/L**			**StD%**
0.5 %	549	±	40	7.3	157	±	2	1.0	488	±	7	1.4
0.5 %	598	±	8	1.3	150	±	0	0.3	471	±	10	2.1
1 %	614	±	40	6.5	164	±	1	0.4	491	±	18	3.7
1 %	432	±	22	5.0	162	±	1	0.9	510	±	24	4.8
1.5 %	609	±	11	1.8	166	±	1	0.6	489	±	49	10.1
1.5 %	626	±	20	3.1	172	±	0	0.1	501	±	34	6.8
2 %	566	±	26	4.6	173	±	0	0.03	520	±	26	5.0
2 %	541	±	5	0.9	174	±	0	0.01	518	±	20	3.9
2.5 %	613	±	11	1.7	181	±	1	0.6	542	±	12	2.3
2.5 %	350	±	9	2.6	183	±	2	1.2	554	±	20	3.6
3 %	622	±	11	1.7	196	±	3	1.7	554	±	25	4.5
3 %	622	±	11	1.7	198	±	2	1.2	567	±	2	0.3
3.5 %	531	±	10	1.9	197	±	1	0.7	550	±	20	3.7
3.5 %	570	±	41	7.1	203	±	3	1.7	555	±	44	7.9
4 %	576	±	5	0.9	206	±	1	0.7	549	±	50	9.1
4 %	507	±	6	1.1	203	±	0	0.2	553	±	35	6.3
5 %	621	±	11	1.7	213	±	2	0.7	557	±	31	5.6
5 %	509	±	9	1.9	219	±	2	0.8	574	±	30	5.2
10 %	601	±	5	0.8	286	±	2	0.5	688	±	34	4.9
10 %	393	±	8	2.0	284	±	3	1.0	677	±	42	6.2

Table A-7d. Atomic Absorption Spectrophotometry Data from the Primary Adsorption Isotherm Experiment: Clinoptilolite

Weight % of Clinoptilolite	Sodium mg/L			StD%	Magnesium mg/L			StD%	Calcium mg/L			StD%
0.5 %	19.0	±	0.6	3.4	2.8	±	0.00	0.0	13.5	±	0.1	0.8
0.5 %	20.9	±	0.0	0.1	2.9	±	0.03	1.0	14.0	±	0.1	0.8
1 %	26.0	±	0.4	1.5	2.3	±	0.03	1.3	9.7	±	0.2	1.7
1 %	25.6	±	0.1	0.2	2.2	±	0.005	0.2	9.9	±	0.1	0.8
1.2 %	22.8	±	3.1	13.6	2.2	±	0.02	0.9	9.8	±	0.2	2.1
1.2 %	27.4	±	0.8	2.9	2.0	±	0.02	0.9	8.9	±	0.2	2.7
1.4 %	27.9	±	1.2	4.3	1.9	±	0.03	1.7	8.5	±	0.5	5.5
1.4 %	26.5	±	0.1	0.4	1.9	±	0.01	0.6	7.9	±	0.3	4.4
1.6 %	32.9	±	0.8	2.4	1.7	±	0.01	0.9	7.0	±	0.4	6.4
1.6 %	24.9	±	1.2	4.7	1.7	±	0.04	2.6	6.9	±	0.4	5.5
1.8 %	36.1	±	0.4	1.1	1.6	±	0.07	4.7	5.6	±	0.1	1.6
1.8 %	29.7	±	0.4	1.4	1.6	±	0.05	3.4	5.5	±	0.02	0.3
2 %	33.5	±	0.8	2.3	1.3	±	0.06	4.7	4.5	±	0.001	0.01
2 %	34.2	±	1.1	3.3	1.4	±	0.06	4.5	5.3	±	0.04	0.7
2.5 %	35.4	±	1.5	4.2	1.1	±	0.07	6.4	4.2	±	0.03	0.7
2.5 %	37.5	±	1.1	3.0	1.1	±	0.05	4.6	4.3	±	0.01	0.2
5 %	49.4	±	0.8	1.6	0.7	±	0.09	13.4	2.2	±	0.04	1.8
5 %	45.7	±	1.5	3.3	0.6	±	0.09	15.1	2.1	±	0.1	4.6
10 %	59.5	±	0.8	1.4	0.4	±	0.08	18.0	1.3	±	0.04	2.9
10 %	61.8	±	0.1	0.2	0.5	±	0.11	20.4	1.4	±	0.1	3.7
Clinoptilolite	**mmol/L**			**StD%**	**mmol/L**			**StD%**	**mmol/L**			**StD%**
0.5 %	827	±	28	3.4	117	±	0	0.0	336	±	3	0.8
0.5 %	909	±	1	0.1	118	±	1	1.0	349	±	3	0.8
1 %	1132	±	17	1.5	93	±	1	1.3	243	±	4	1.7
1 %	1114	±	2	0.2	92	±	0	0.2	247	±	2	0.8
1.2 %	991	±	135	13.6	89	±	1	0.9	244	±	5	2.1
1.2 %	1191	±	34	2.9	80	±	1	0.9	221	±	6	2.7
1.4 %	1211	±	52	4.3	78	±	1	1.7	212	±	12	5.5
1.4 %	1151	±	5	0.4	77	±	0	0.6	196	±	9	4.4
1.6 %	1433	±	34	2.4	70	±	1	0.9	174	±	11	6.4
1.6 %	1085	±	51	4.7	71	±	2	2.6	173	±	10	5.5
1.8 %	1569	±	18	1.1	65	±	3	4.7	141	±	2	1.6
1.8 %	1294	±	18	1.4	65	±	2	3.4	136	±	0	0.3
2 %	1459	±	34	2.3	53	±	2	4.7	113	±	0	0.01
2 %	1487	±	49	3.3	58	±	3	4.5	132	±	1	0.7
2.5 %	1538	±	65	4.2	46	±	3	6.4	104	±	1	0.7
2.5 %	1633	±	49	3.0	45	±	2	4.6	108	±	0	0.2
5 %	2149	±	34	1.6	27	±	4	13.4	55	±	1	1.8
5 %	1988	±	65	3.3	26	±	4	15.1	53	±	2	4.6
10 %	2587	±	36	1.4	18	±	3	18.0	33	±	1	2.9
10 %	2686	±	5	0.2	21	±	4	20.4	34	±	1	3.7

Table A-7e. Atomic Absorption Spectrophotometry Data from the Primary Adsorption Isotherm Experiment: Hanford Soil

Hanford Soil	Sodium		Magnesium		Calcium	
	mg/L	StD%	mg/L	StD%	mg/L	StD%
100%	12.3 ± 0.3	2.5	3.7 ± 0.04	1.0	19.0	
100%	11.3 ± 1.0	9.0	3.6 ± 0.01	0.3	19.2	
100%	11.8 ± 0.3	2.7	3.8 ± 0.01	0.3	20.7	
100%	14.0 ± 0.0	0.3	3.8 ± 0.07	1.7	22.1	
100%	12.5 ± 0.0	0.3	4.5 ± 0.07	1.6	15.8 ± 0.4	2.8
100%	17.1 ± 0.4	2.3	4.5 ± 0.05	1.0	15.4 ± 0.2	1.4
Average ± Standard deviation	13.2 ± 2.1	16.3	4.0 ± 0.4	9.6	18.7 ± 2.6	14.1
	mmol/L	**StD%**	**mmol/L**	**StD%**	**mmol/L**	**StD%**
100%	0.54 ± 0.01	2.5	0.15 ± 0.001	1.0	0.47	
100%	0.49 ± 0.04	9.0	0.15 ± 0.000	0.3	0.48	
100%	0.51 ± 0.01	2.7	0.16 ± 0.001	0.3	0.52	
100%	0.61 ± 0.00	0.3	0.16 ± 0.003	1.7	0.55	
100%	0.54 ± 0.00	0.3	0.18 ± 0.003	1.6	0.39 ± 0.01	2.8
100%	0.75 ± 0.02	2.3	0.18 ± 0.002	1.0	0.39 ± 0.01	1.4
Average ± Standard deviation	0.6 ± 0.1	16.3	0.16 ± 0.02	9.6	0.5 ± 0.1	14.1

Table A-8a. Inductively Coupled Plasma-Mass Spectrometry Data from the Primary Adsorption Isotherm Experiment: NC Apatite (1 of 4)

Weight % of NC Apatite	Chromium µg/L	Manganese µg/L	Iron µg/L	Copper µg/L	Zinc µg/L
0.5 %	0.4 ± 0.0	7.5 ± 0.0	83 ± 2	4.2 ± 0.1	<1.4
0.5 %	0.3 ± 0.1	5.3 ± 0.0	73 ± 2	0.8 ± 0.0	1.4
1 %	0.3 ± 0.0	6.3 ± 0.1	83 ± 2	0.7 ± 0.0	<1.4
1 %	<0.2	8.4 ± 0.0	97 ± 3	<0.5	<1.4
1.5 %	<0.2	7.5 ± 0.0	61 ± 4	1.6 ± 0.0	2.6 ± 0.1
1.5 %	<0.2	5.6 ± 0.1	46 ± 1	1.0 ± 0.1	<1.4
2 %	<0.2	6.4 ± 0.1	54 ± 2	0.6 ± 0.0	<1.4
2 %	<0.2	7.2 ± 0.1	62 ± 3	1.1 ± 0.0	1.7 ± 0.2
2.25 %	<0.2	5.9 ± 0.1	45 ± 1	1.2 ± 0.1	<1.4
2.25 %	<0.2	9.1 ± 0.1	78 ± 2	1.2 ± 0.0	<1.4
2.5 %	<0.2	6.0 ± 0.1	51 ± 8	0.7 ± 0.0	<1.4
2.5 %	<0.2	7.1 ± 0.1	72 ± 4	0.6 ± 0.0	2.1 ± 0.2
3 %	0.3 ± 0.0	6.5 ± 0.0	57 ± 4	0.8 ± 0.0	2.0 ± 0.1
3 %	0.3 ± 0.0	6.8 ± 0.0	68 ± 4	0.8 ± 0.1	<1.4
3.5 %	0.2 ± 0.0	6.9 ± 0.1	52 ± 4	0.6 ± 0.0	<1.4
3.5 %	<0.2	6.3 ± 0.1	50 ± 3	0.6 ± 0.0	<1.4
5 %	<0.2	13.0	108	0.7	1.9
5 %	<0.2	10.7	88	<0.5	<1.4
10 %	<0.2	13.2 ± 0.0	118 ± 1	0.6 ± 0.0	<1.4
10 %	<0.2	14.6 ± 0.1	113 ± 3	1.1 ± 0.0	2.3 ± 0.0
NC Apatite	**µmol/L**	**µmol/L**	**µmol/L**	**µmol/L**	**µmol/L**
0.5 %	7.1 ± 0.4	136 ± 1	1492 ± 28	65 ± 1	< 21
0.5 %	5.3 ± 1.0	96 ± 0	1299 ± 34	13 ± 1	< 21
1 %	6.6 ± 0.9	115 ± 1	1493 ± 31	12 ± 0	< 21
1 %	< 3.8	153 ± 0	1734 ± 50	< 8	< 21
1.5 %	< 3.8	136 ± 0	1097 ± 67	26 ± 1	39 ± 1
1.5 %	< 3.8	102 ± 2	830 ± 17	16 ± 1	< 21
2 %	< 3.8	116 ± 1	973 ± 40	9 ± 1	< 21
2 %	< 3.8	131 ± 1	1111 ± 60	18 ± 1	26 ± 3
2.25 %	< 3.8	107 ± 1	808 ± 20	20 ± 1	< 21
2.25 %	< 3.8	165 ± 1	1401 ± 42	19 ± 1	< 21
2.5 %	< 3.8	109 ± 2	917 ± 149	10 ± 0	< 21
2.5 %	< 3.8	129 ± 2	1283 ± 76	10 ± 1	32 ± 4
3 %	5.8 ± 0.7	119 ± 1	1028 ± 78	13 ± 0	30 ± 1
3 %	5.1 ± 0.8	124 ± 0	1220 ± 71	12 ± 1	< 21
3.5 %	4.2 ± 0.8	125 ± 1	935 ± 71	10 ± 0	< 21
3.5 %	< 3.8	115 ± 1	890 ± 47	10 ± 1	< 21
5 %	< 3.8	236	1937	10	29 ± 0
5 %	< 3.8	195	1568	< 8	< 21
10 %	< 3.8	240 ± 1	2115 ± 19	9 ± 0	< 21
10 %	< 3.8	266 ± 1	2030 ± 56	18 ± 0	34 ± 0

Table A-8a. Inductively Coupled Plasma-Mass Spectrometry Data from the Primary Adsorption Isotherm Experiment: NC Apatite (2 of 4)

Weight % of NC-Apatite	Cesium µg/L	Strontium µg/L	Barium µg/L	Arsenic µg/L	Lead µg/L
0.5 %	<0.01	74.6 ± 0.5	13.0 ± 0.08	0.33 ± 0.05	0.39 ± 0.008
0.5 %	<0.01	61.2 ± 0.3	10.4 ± 0.05	0.32 ± 0.03	0.13 ± 0.012
1 %	<0.01	68.1 ± 0.5	11.3 ± 0.03	0.28 ± 0.04	0.25 ± 0.004
1 %	<0.01	70.6 ± 0.6	12.6 ± 0.13	0.33 ± 0.03	<0.1
1.5 %	<0.01	77.0 ± 0.2	12.5 ± 0.10	0.36 ± 0.03	<0.1
1.5 %	<0.01	66.7 ± 0.6	11.0 ± 0.03	0.36 ± 0.05	0.19 ± 0.007
2 %	<0.01	75.5 ± 0.4	11.6 ± 0.10	0.37 ± 0.03	<0.1
2 %	<0.01	76.5 ± 1.0	12.1 ± 0.14	0.41 ± 0.03	0.13 ± 0.013
2.25 %	0.026 ± 0.004	73.5 ± 0.6	11.3 ± 0.12	0.37 ± 0.04	0.31 ± 0.002
2.25 %	0.011 ± 0.001	88.2 ± 0.8	13.6 ± 0.03	0.42 ± 0.04	0.12 ± 0.004
2.5 %	<0.01	73.7 ± 0.6	11.0 ± 0.07	0.42 ± 0.05	<0.1
2.5 %	<0.01	82.2 ± 0.4	12.3 ± 0.04	0.41 ± 0.02	<0.1
3 %	<0.01	83.2 ± 0.9	11.8 ± 0.20	0.45 ± 0.06	<0.1
3 %	<0.01	81.6 ± 0.5	11.9 ± 0.12	0.41 ± 0.03	0.30 ± 0.008
3.5 %	<0.01	85.7 ± 1.0	12.9 ± 0.11	0.43 ± 0.04	<0.1
3.5 %	<0.01	80.4 ± 0.7	12.3 ± 0.05	0.40 ± 0.02	<0.1
5 %	<0.01	117	15.3	0.44	<0.1
5 %	<0.01	99.4	13.2	0.42	<0.1
10 %	<0.01	179 ± 1.9	15.5 ± 0.07	0.66 ± 0.00	<0.1
10 %	<0.01	174 ± 2.3	15.3 ± 0.11	0.54 ± 0.04	<0.1
NC Apatite	**µmol/L**	**µmol/L**	**µmol/L**	**µmol/L**	**µmol/L**
0.5 %	<0.08	851 ± 6	95 ± 1	4.4 ± 0.6	1.86 ± 0.04
0.5 %	<0.08	698 ± 3	75 ± 0	4.2 ± 0.3	0.65 ± 0.06
1 %	<0.08	777 ± 5	82 ± 0	3.8 ± 0.5	1.20 ± 0.02
1 %	<0.08	806 ± 6	92 ± 1	4.3 ± 0.3	< 0.5
1.5 %	<0.08	878 ± 3	91 ± 1	4.8 ± 0.4	< 0.5
1.5 %	<0.08	762 ± 7	80 ± 0	4.8 ± 0.7	0.92 ± 0.03
2 %	<0.08	862 ± 5	85 ± 1	4.9 ± 0.3	< 0.5
2 %	<0.08	873 ± 12	88 ± 1	5.5 ± 0.3	0.62 ± 0.06
2.25 %	0.20 ± 0.03	839 ± 6	82 ± 1	5.0 ± 0.5	1.49 ± 0.01
2.25 %	0.08 ± 0.01	1007 ± 9	99 ± 0	5.6 ± 0.5	0.58 ± 0.02
2.5 %	<0.08	841 ± 7	80 ± 1	5.6 ± 0.7	< 0.5
2.5 %	<0.08	938 ± 5	90 ± 0	5.5 ± 0.2	< 0.5
3 %	<0.08	950 ± 10	86 ± 1	6.0 ± 0.8	< 0.5
3 %	<0.08	931 ± 6	87 ± 1	5.5 ± 0.4	1.42 ± 0.04
3.5 %	<0.08	978 ± 12	94 ± 1	5.8 ± 0.6	< 0.5
3.5 %	<0.08	918 ± 8	90 ± 0	5.3 ± 0.3	< 0.5
5 %	<0.08	1339 ± 0	111 ± 0	5.9 ± 0.0	< 0.5
5 %	<0.08	1134 ± 0	96 ± 0	5.6 ± 0.0	< 0.5
10 %	<0.08	2048 ± 22	113 ± 1	8.8 ± 0.1	< 0.5
10 %	<0.08	1991 ± 27	111 ± 1	7.2 ± 0.6	< 0.5

Table A-8a. Inductively Coupled Plasma-Mass Spectrometry Data from the Primary Adsorption Isotherm Experiment: NC Apatite (3 of 4)

Weight % of NC Apatite	Yttrium µg/L			Lanthanum µg/L			Praeseodymium µg/L			Samarium µg/L			Europium µg/L		
0.5 %	0.07	±	0.01	0.16	±	0.01	0.08	±	0.01	<0.05			0.11	±	0.01
0.5 %	0.13	±	0.01	0.09	±	0.01	<0.05			<0.05			<0.05		
1 %	0.18	±	0.02	0.19	±	0.01	<0.05			<0.05			<0.05		
1 %	0.23	±	0.01	0.19	±	0.01	0.07	±	0.00	0.06	±	0.01	<0.05		
1.5 %	0.06			0.05	±	0.01	<0.05			<0.05			<0.05		
1.5 %	0.09	±	0.01	0.08	±	0.01	<0.05			<0.05			<0.05		
2 %	0.10	±	0.01	0.07	±	0.01	<0.05			<0.05			<0.05		
2 %	0.11	±	0.03	0.09	±	0.01	<0.05			<0.05			<0.05		
2.25 %	0.08	±	0.02	0.08	±	0.00	<0.05			<0.05			0.06	±	0.01
2.25 %	0.11	±	0.01	0.08	±	0.02	<0.05			<0.05			<0.05		
2.5 %	0.12	±	0.03	0.07	±	0.01	<0.05			<0.05			<0.05		
2.5 %	0.26	±	0.05	0.09	±	0.01	<0.05			<0.05			<0.05		
3 %	0.08	±	0.03	0.05	±	0.00	<0.05			<0.05			<0.05		
3 %	0.46	±	0.02	0.31	±	0.04	0.08	±	0.02	<0.05			0.12	±	0.01
3.5 %	0.29	±	0.03	0.12	±	0.01	<0.05			<0.05			<0.05		
3.5 %	0.12	±	0.02	0.10	±	0.01	<0.05			<0.05			<0.05		
5 %	<.06			0.05			<0.05			<0.05			<0.05		
5 %	<.06			<0.05			<0.05			<0.05			<0.05		
10 %	<.06			<0.05			<0.05			<0.05			<0.05		
10 %	<.06			<0.05			<0.05			<0.05			<0.05		
NC Apatite	µmol/L			µmol/L			µmol/L			µmol/L			µmol/L		
0.5 %	0.8	±	0.1	1.2	±	0.1	0.55	±	0.09	< 0.3			0.74	±	0.05
0.5 %	1.5	±	0.1	0.7	±	0.1	<0.35			< 0.3			<0.33		
1 %	2.1	±	0.2	1.4	±	0.1	<0.35			< 0.3			<0.33		
1 %	2.6	±	0.1	1.3	±	0.1	0.47	±	0.03	0.4	±	0.1	<0.33		
1.5 %	< 0.7			0.4	±	0.1	<0.35			< 0.3			<0.33		
1.5 %	1.0	±	0.2	0.6	±	0.1	<0.35			< 0.3			<0.33		
2 %	1.1	±	0.1	0.5	±	0.1	<0.35			< 0.3			<0.33		
2 %	1.3	±	0.3	0.6	±	0.0	<0.35			< 0.3			<0.33		
2.25 %	0.9	±	0.2	0.6	±	0.0	<0.35			< 0.3			0.39	±	0.04
2.25 %	1.2	±	0.1	0.6	±	0.1	<0.35			< 0.3			<0.33		
2.5 %	1.4	±	0.3	0.5	±	0.1	<0.35			< 0.3			<0.33		
2.5 %	2.9	±	0.6	0.6	±	0.1	<0.35			< 0.3			<0.33		
3 %	0.9	±	0.3	0.4	±	0.0	<0.35			< 0.3			<0.33		
3 %	5.1	±	0.2	2.3	±	0.3	0.59	±	0.11	< 0.3			0.81	±	0.06
3.5 %	3.2	±	0.3	0.9	±	0.1	<0.35			< 0.3			<0.33		
3.5 %	1.4	±	0.2	0.7	±	0.0	<0.35			< 0.3			<0.33		
5 %	< 0.7			< 0.4			<0.35			< 0.3			<0.33		
5 %	< 0.7			< 0.4			<0.35			< 0.3			<0.33		
10 %	< 0.7			< 0.4			<0.35			< 0.3			<0.33		
10 %	< 0.7			< 0.4			<0.35			< 0.3			<0.33		

Table A-8a. Inductively Coupled Plasma-Mass Spectrometry Data from the Primary Adsorption Isotherm Experiment: NC Apatite (4 of 4)

Weight % of NC Apatite	Gadolinium µg/L	Dysprosium µg/L	Holmium µg/L	Erbium µg/L	Ytterbium µg/L
0.5 %	<0.02	0.08 ± 0.01	0.03 ± 0.00	<0.02	<0.02
0.5 %	0.04 ± 0.00	<0.02	<0.02	<0.02	<0.02
1 %	0.03 ± 0.01	0.05 ± 0.01	0.02 ± 0.01	<0.02	<0.02
1 %	0.08 ± 0.02	0.04 ± 0.00	0.10 ± 0.01	0.04 ± 0.00	0.03 ± 0.01
1.5 %	<0.02	0.07 ± 0.02	<0.02	<0.02	<0.02
1.5 %	<0.02	0.11 ± 0.01	<0.02	<0.02	<0.02
2 %	0.04 ± 0.01	0.08 ± 0.01	<0.02	<0.02	<0.02
2 %	<0.02	0.14 ± 0.00	<0.02	<0.02	<0.02
2.25 %	<0.02	0.05 ± 0.01	0.03 ± 0.00	<0.02	<0.02
2.25 %	<0.02	0.04 ± 0.01	0.02 ± 0.00	<0.02	<0.02
2.5 %	<0.02	0.10 ± 0.02	0.02 ± 0.00	<0.02	<0.02
2.5 %	0.03 ± 0.01	0.04 ± 0.01	<0.02	0.03 ± 0.01	<0.02
3 %	<0.02	0.05 ± 0.00	<0.02	<0.02	<0.02
3 %	0.06 ± 0.01	0.26 ± 0.03	0.32 ± 0.01	<0.02	<0.02
3.5 %	<0.02	0.06 ± 0.00	0.03 ± 0.01	<0.02	<0.02
3.5 %	<0.02	<0.02	<0.02	<0.02	<0.02
5 %	<0.02	<0.02	<0.02	<0.02	<0.02
5 %	<0.02	0.04	<0.02	<0.02	<0.02
10 %	<0.02	<0.02	<0.02	<0.02	<0.02
10 %	<0.02	<0.02	<0.02	<0.02	<0.02
NC Apatite	µmol/L	µmol/L	µmol/L	µmol/L	µmol/L
0.5 %	<0.13	0.47 ± 0.07	0.20 ± 0.03	<0.12	<0.12
0.5 %	0.27 ± 0.01	<0.12	<0.12	<0.12	<0.12
1 %	0.21 ± 0.09	0.32 ± 0.07	0.15 ± 0.03	<0.12	<0.12
1 %	0.49 ± 0.12	0.27 ± 0.01	0.61 ± 0.06	0.24 ± 0.03	0.18 ± 0.05
1.5 %	<0.13	0.42 ± 0.12	<0.12	<0.12	<0.12
1.5 %	<0.13	0.70 ± 0.06	<0.12	<0.12	<0.12
2 %	0.23 ± 0.06	0.49 ± 0.05	<0.12	<0.12	<0.12
2 %	<0.13	0.84 ± 0.02	<0.12	<0.12	<0.12
2.25 %	<0.13	0.30 ± 0.04	0.21 ± 0.03	<0.12	<0.12
2.25 %	<0.13	0.23 ± 0.04	0.14 ± 0.02	<0.12	<0.12
2.5 %	<0.13	0.62 ± 0.14	0.13 ± 0.01	<0.12	<0.12
2.5 %	0.17 ± 0.09	0.23 ± 0.05	<0.12	0.16 ± 0.09	<0.12
3 %	<0.13	0.33 ± 0.03	<0.12	<0.12	<0.12
3 %	0.35 ± 0.08	1.62 ± 0.21	1.92 ± 0.03	<0.12	<0.12
3.5 %	<0.13	0.38 ± 0.02	0.16 ± 0.08	<0.12	<0.12
3.5 %	<0.13	<0.12	<0.12	<0.12	<0.12
5 %	<0.13	<0.12	<0.12	<0.12	<0.12
5 %	<0.13	0.25 ± 0.00	<0.12	<0.12	<0.12
10 %	<0.13	<0.12	<0.12	<0.12	<0.12
10 %	<0.13	<0.12	<0.12	<0.12	<0.12

Table A-8b. Inductively Coupled Plasma-Mass Spectrometry Data from the Primary Adsorption Isotherm Experiment: Bone Char (1 of 4)

Weight % of	Chromium	Manganese	Iron	Copper	Zinc
Bone Char	µg/L	µg/L	µg/L	µg/L	µg/L
0.5 %	0.46 ± 0.05	6.5 ± 0.10	78.1 ± 3.6	0.88 ± 0.02	<1.4
0.5 %	<0.2	7.1 ± 0.06	77.8 ± 6.0	<0.5	<1.4
1 %	<0.2	6.5 ± 0.03	62.9 ± 0.9	<0.5	<1.4
1 %	<0.2	9.5 ± 0.07	102 ± 5.1	0.84 ± 0.03	3.01 ± 0.05
1.5 %	<0.2	5.9 ± 0.02	62.2 ± 1.5	0.55 ± 0.04	1.45 ± 0.07
1.5 %	<0.2	3.5 ± 0.07	56.6 ± 2.9	0.51 ± 0.03	<1.4
2 %	<0.2	3.3 ± 0.02	28.6 ± 2.0	<0.5	1.40 ± 0.05
2 %	<0.2	2.5 ± 0.11	29.4 ± 3.5	0.97 ± 0.06	<1.4
2.25 %	<0.2	3.8 ± 0.14	47.7 ± 4.2	1.13 ± 0.05	2.23 ± 0.05
2.25 %	<0.2	3.6 ± 0.06	55.1 ± 2.2	0.57 ± 0.02	<1.4
2.5 %	0.21 ± 0.02	1.11 ± 0.04	na	1.14 ± 0.01	<1.4
2.5 %	<0.2	1.12 ± 0.02	na	0.65 ± 0.03	2.06 ± 0.07
3 %	<0.2	0.91 ± 0.04	na	0.56 ± 0.03	7.48 ± 0.12
3 %	<0.2	0.89 ± 0.00	na	0.54 ± 0.04	<1.4
3.5 %	0.27 ± 0.04	0.66 ± 0.03	na	1.94 ± 0.09	4.16 ± 0.06
3.5 %	0.33 ± 0.01	1.64 ± 0.02	na	<0.5	<1.4
5 %	0.64 ± 0.05	0.30 ± 0.01	na	0.60 ± 0.03	3.53 ± 0.17
5 %	0.56 ± 0.03	0.36 ± 0.02	na	0.90 ± 0.03	4.67 ± 0.11
10 %	1.31 ± 0.03	0.25 ± 0.01	na	<0.5	<1.4
10 %	1.38 ± 0.03	0.18 ± 0.01	na	<0.5	<1.4
Bone Char	µmol/L	µmol/L	µmol/L	µmol/L	µmol/L
0.5 %	8.9 ± 1.0	119 ± 1.8	1399 ± 64	13.9 ± 0.3	< 21
0.5 %	< 3.8	128 ± 1.1	1393 ± 107	< 8	< 21
1 %	< 3.8	118 ± 0.6	1126 ± 16	< 8	< 21
1 %	< 3.8	173 ± 1.2	1832 ± 91	13.2 ± 0.4	46 ± 1
1.5 %	< 3.8	108 ± 0.3	1113 ± 28	8.6 ± 0.7	22 ± 1
1.5 %	< 3.8	64.5 ± 1.3	1014 ± 52	8.0 ± 0.5	< 21
2 %	< 3.8	60.2 ± 0.3	513 ± 35	< 8	21 ± 1
2 %	< 3.8	45.3 ± 2.0	527 ± 62	15.3 ± 1.0	< 21
2.25 %	< 3.8	68.5 ± 2.6	854 ± 76	17.8 ± 0.7	34 ± 1
2.25 %	< 3.8	65.5 ± 1.1	986 ± 39	8.9 ± 0.3	< 21
2.5 %	4.0 ± 0.4	20.3 ± 0.7	na	17.9 ± 0.1	< 21
2.5 %	< 3.8	20.4 ± 0.5	na	10.3 ± 0.4	32 ± 1
3 %	< 3.8	16.5 ± 0.7	na	8.9 ± 0.5	114 ± 2
3 %	< 3.8	16.2 ± 0.0	na	8.5 ± 0.6	< 21
3.5 %	5.3 ± 0.8	11.9 ± 0.5	na	30.5 ± 1.5	64 ± 1
3.5 %	6.3 ± 0.3	29.8 ± 0.4	na	< 8 ±	< 21
5 %	12.3 ± 1.1	5.5 ± 0.2	na	9.5 ± 0.5	54 ± 3
5 %	10.8 ± 0.6	6.6 ± 0.3	na	14.1 ± 0.4	71 ± 2
10 %	25.1 ± 0.6	4.6 ± 0.3	na	< 8	< 21
10 %	26.6 ± 0.6	3.3 ± 0.2	na	< 8	< 21

Table A-8b. Inductively Coupled Plasma-Mass Spectrometry Data from the Primary Adsorption Isotherm Experiment: Bone Char (2 of 4)

Weight % of Bone Char	Cesium µg/L			Strontium µg/L			Barium µg/L			Arsenic µg/L			Lead µg/L		
0.5 %	<0.01			64.3	±	0.4	12.2	±	0.04	0.39	±	0.05	0.11	±	0.002
0.5 %	<0.01			62.2	±	0.4	11.9	±	0.05	0.41	±	0.08	0.24	±	0.002
1 %	<0.01			62.6	±	0.1	12.5	±	0.04	0.44	±	0.01	<0.1		
1 %	0.015	±	0.003	70.8	±	0.8	14.3	±	0.04	0.40	±	0.08	<0.1		
1.5 %	<0.01			65.0	±	0.8	13.8	±	0.14	0.36	±	0.03	<0.1		
1.5 %	0.048	±	0.004	54.3	±	0.4	10.4	±	0.10	0.38	±	0.04	0.18	±	0.01
2 %	<0.01			56.2	±	0.2	11.3	±	0.02	0.36	±	0.02	<0.1		
2 %	0.017	±	0.003	50.0	±	0.5	9.8	±	0.13	0.29	±	0.05	<0.1		
2.25 %	0.013	±	0.001	63.1	±	0.4	13.5	±	0.02	0.33	±	0.04	<0.1		
2.25 %	<0.01			58.0	±	0.1	12.6	±	0.02	0.35	±	0.12	<0.1		
2.5 %	<0.01			49.8	±	0.4	10.0	±	0.18	0.39	±	0.02	<0.1		
2.5 %	<0.01			50.9	±	0.3	10.1	±	0.06	0.36	±	0.02	<0.1		
3 %	<0.01			47.5	±	0.8	9.7	±	0.15	0.27	±	0.02	0.23	±	0.01
3 %	<0.01			49.4	±	0.1	10.2	±	0.11	0.32	±	0.05	<0.1		
3.5 %	0.015	±	0.002	46.5	±	0.7	9.9	±	0.09	0.27	±	0.03	<0.1		
3.5 %	<0.01			50.0	±	0.4	11.2	±	0.06	0.30	±	0.03	<0.1		
5 %	<0.01			30.7	±	0.2	10.7	±	0.03	0.22	±	0.01	<0.1		
5 %	<0.01			36.1	±	0.0	10.7	±	0.09	0.22	±	0.02	<0.1		
10 %	<0.01			21.2	±	0.2	10.1	±	0.03	0.25	±	0.03	<0.1		
10 %	<0.01			21.6	±	0.2	10.7	±	0.11	0.29	±	0.06	<0.1		
Bone Char	**µmol/L**			**µmol/L**			**µmol/L**			**µmol/L**			**µmol/L**		
0.5 %	< 0.08			733	±	4	88.8	±	0.3	5.2	±	0.6	0.55	±	0.01
0.5 %	< 0.08			710	±	5	86.8	±	0.4	5.5	±	1.0	1.16	±	0.01
1 %	< 0.08			715	±	1	90.9	±	0.3	5.9	±	0.1	< 0.5		
1 %	0.11	±	0.02	808	±	9	104	±	0.3	5.4	±	1.1	< 0.5		
1.5 %	< 0.08			742	±	9	100	±	1.0	4.8	±	0.4	< 0.5		
1.5 %	0.36	±	0.03	620	±	5	75.8	±	0.7	5.1	±	0.5	0.86	±	0.03
2 %	< 0.08			642	±	2	82.0	±	0.1	4.8	±	0.3	< 0.5		
2 %	0.13	±	0.02	570	±	5	71.6	±	0.9	3.9	±	0.7	< 0.5		
2.25 %	0.10	±	0.01	720	±	5	98.1	±	0.2	4.5	±	0.5	< 0.5		
2.25 %	< 0.08			662	±	1	92.1	±	0.1	4.6	±	1.6	< 0.5		
2.5 %	< 0.08			568	±	4	72.5	±	1.3	5.1	±	0.3	< 0.5		
2.5 %	< 0.08			581	±	3	73.4	±	0.5	4.8	±	0.3	< 0.5		
3 %	< 0.08			542	±	9	70.9	±	1.1	3.6	±	0.2	1.13	±	0.06
3 %	< 0.08			564	±	2	74.6	±	0.8	4.2	±	0.7	< 0.5		
3.5 %	0.11	±	0.01	530	±	8	72.1	±	0.6	3.6	±	0.4	< 0.5		
3.5 %	< 0.08			570	±	4	81.9	±	0.4	4.1	±	0.4	< 0.5		
5 %	< 0.08			350	±	2	77.7	±	0.2	2.9	±	0.1	< 0.5		
5 %	< 0.08			412	±	0	77.9	±	0.7	2.9	±	0.3	< 0.5		
10 %	< 0.08			242	±	2	73.4	±	0.2	3.3	±	0.5	< 0.5		
10 %	< 0.08			247	±	2	77.6	±	0.8	3.8	±	0.9	< 0.5		

Table A-8b. Inductively Coupled Plasma-Mass Spectrometry Data from the Primary Adsorption Isotherm Experiment: Bone Char (3 of 4)

Weight % of Bone Char	Yttrium µg/L	Lanthanum µg/L	Praeseodymium µg/L	Samarium µg/L	Europium µg/L
0.5 %	0.67 ± 0.01	0.05 ± 0.02	<0.05	<0.05	<0.05
0.5 %	0.16 ± 0.02	0.13 ± 0.04	<0.05	<0.05	<0.05
1 %	0.13 ± 0.03	0.18 ± 0.03	<0.05	<0.05	0.06 ± 0.01
1 %	0.20 ± 0.03	0.14 ± 0.03	<0.05	<0.05	<0.05
1.5 %	0.09 ± 0.03	0.08 ± 0.02	<0.05	<0.05	0.07 ± 0.01
1.5 %	0.20 ± 0.01	0.22 ± 0.03	0.05 ± 0.01	<0.05	0.07 ± 0.01
2 %	0.59 ± 0.02	0.06 ± 0.02	<0.05	<0.05	<0.05
2 %	0.12 ± 0.01	0.08 ± 0.01	<0.05	<0.05	<0.05
2.25 %	0.08 ± 0.01	0.06 ± 0.00	<0.05	<0.05	<0.05
2.25 %	0.25 ± 0.03	0.21 ± 0.03	0.06 ± 0.01	<0.05	0.07 ± 0.00
2.5 %	<0.06	0.08 ± 0.02	<0.05	<0.05	0.07 ± 0.02
2.5 %	<0.06	<0.05	<0.05	<0.05	0.09 ± 0.01
3 %	<0.06	<0.05	<0.05	<0.05	<0.05
3 %	<0.06	<0.05	<0.05	<0.05	0.08 ± 0.02
3.5 %	<0.06	<0.05	<0.05	<0.05	0.15 ± 0.01
3.5 %	<0.06	<0.05	<0.05	<0.05	<0.05
5 %	<0.06	<0.05	<0.05	<0.05	0.20 ± 0.01
5 %	<0.06	<0.05	<0.05	<0.05	<0.05
10 %	<0.06	<0.05	<0.05	<0.05	<0.05
10 %	0.26 ± 0.01	0.23 ± 0.01	0.05 ± 0.01	<0.05	0.10 ± 0.02
Bone Char	**µmol/L**	**µmol/L**	**µmol/L**	**µmol/L**	**µmol/L**
0.5 %	7.6 ± 0.1	0.4 ± 0.1	< 0.35	< 0.3	< 0.33
0.5 %	1.8 ± 0.2	0.9 ± 0.3	< 0.35	< 0.3	< 0.33
1 %	1.4 ± 0.3	1.3 ± 0.2	< 0.35	< 0.3	0.39 ± 0.08
1 %	2.3 ± 0.4	1.0 ± 0.2	< 0.35	< 0.3	< 0.33
1.5 %	1.0 ± 0.3	0.6 ± 0.1	< 0.35	< 0.3	0.49 ± 0.04
1.5 %	2.2 ± 0.1	1.6 ± 0.2	0.39 ± 0.07	< 0.3	0.43 ± 0.05
2 %	6.6 ± 0.3	0.4 ± 0.1	< 0.35	< 0.3	< 0.33
2 %	1.4 ± 0.1	0.6 ± 0.1	< 0.35	< 0.3	< 0.33
2.25 %	0.9 ± 0.1	0.4 ± 0.0	< 0.35	< 0.3	< 0.33
2.25 %	2.9 ± 0.4	1.5 ± 0.2	0.43 ± 0.07	< 0.3	0.45 ± 0.01
2.5 %	< 0.7	0.6 ± 0.2	< 0.35	< 0.3	0.43 ± 0.13
2.5 %	< 0.7	< 0.4	< 0.35	< 0.3	0.59 ± 0.05
3 %	< 0.7	< 0.4	< 0.35	< 0.3	< 0.33
3 %	< 0.7	< 0.4	< 0.35	< 0.3	0.53 ± 0.11
3.5 %	< 0.7	< 0.4	< 0.35	< 0.3	0.97 ± 0.04
3.5 %	< 0.7	< 0.4	< 0.35	< 0.3	< 0.33
5 %	< 0.7	< 0.4	< 0.35	< 0.3	1.30 ± 0.06
5 %	< 0.7	< 0.4	< 0.35	< 0.3	< 0.33
10 %	< 0.7	< 0.4	< 0.35	< 0.3	< 0.33
10 %	2.9 ± 0.1	1.7 ± 0.1	0.39 ± 0.05	< 0.3	0.69 ± 0.11

Table A-8b. Inductively Coupled Plasma-Mass Spectrometry Data from the Primary Adsorption Isotherm Experiment: Bone Char (4 of 4)

Weight % of Bone Char	Gadolinium µg/L	Dysprosium µg/L	Holmium µg/L	Erbium µg/L	Ytterbium µg/L
0.5 %	0.09 ± 0.005	7.40 ± 0.06	0.06 ± 0.003	0.07 ± 0.01	<0.02
0.5 %	<0.02	<0.02	<0.02	<0.02	<0.02
1 %	<0.02	0.09 ± 0.004	0.12 ± 0.002	<0.02	<0.02
1 %	<0.02	<0.02	<0.02	0.03 ± 0.01	<0.02
1.5 %	<0.02	<0.02	<0.02	<0.02	<0.02
1.5 %	<0.02	<0.02	0.03 ± 0.01	0.02 ± 0.01	<0.02
2 %	0.06 ± 0.01	7.75 ± 0.08	0.05 ± 0.01	0.03 ± 0.01	<0.02
2 %	<0.02	0.03 ± 0.00	<0.02	<0.02	<0.02
2.25 %	<0.02	0.09 ± 0.01	<0.02	<0.02	<0.02
2.25 %	0.03 ± 0.02	0.06 ± 0.01	0.02 ± 0.01	0.04 ± 0.01	<0.02
2.5 %	<0.02	0.04 ± 0.01	0.03 ± 0.01	<0.02	<0.02
2.5 %	<0.02	<0.02	<0.02	<0.02	<0.02
3 %	<0.02	<0.02	<0.02	<0.02	<0.02
3 %	<0.02	0.06 ± 0.004	0.03 ± 0.01	<0.02	<0.02
3.5 %	<0.02	0.02 ± 0.002	<0.02	<0.02	<0.02
3.5 %	<0.02	0.04 ± 0.01	<0.02	<0.02	<0.02
5 %	<0.02	<0.02	<0.02	<0.02	<0.02
5 %	0.03 ± 0.02	0.03 ± 0.01	<0.02	<0.02	<0.02
10 %	0.05 ± 0.01	0.48 ± 0.02	<0.02	<0.02	<0.02
10 %	0.09 ± 0.03	0.57 ± 0.02	0.27 ± 0.01	<0.02	<0.02
Bone Char	**µmol/L**	**µmol/L**	**µmol/L**	**µmol/L**	**µmol/L**
0.5 %	0.56 ± 0.03	45.56 ± 0.37	0.38 ± 0.02	0.39 ± 0.05	< 0.12
0.5 %	< 0.13	< 0.12	< 0.12	< 0.12	< 0.12
1 %	< 0.13	0.53 ± 0.03	0.70 ± 0.01	< 0.12	< 0.12
1 %	< 0.13	< 0.12	< 0.12	0.16 ± 0.05	< 0.12
1.5 %	< 0.13	< 0.12	< 0.12	< 0.12	< 0.12
1.5 %	< 0.13	< 0.12	0.16 ± 0.06	0.14 ± 0.08	< 0.12
2 %	0.40 ± 0.09	47.68 ± 0.51	0.32 ± 0.05	0.17 ± 0.08	< 0.12
2 %	< 0.13	0.22 ± 0.02	< 0.12	< 0.12	< 0.12
2.25 %	< 0.13	0.54 ± 0.04	< 0.12	< 0.12	< 0.12
2.25 %	0.17 ± 0.14	0.37 ± 0.03	0.15 ± 0.06	0.21 ± 0.07	< 0.12
2.5 %	< 0.13	0.23 ± 0.04	0.21 ± 0.03	< 0.12	< 0.12
2.5 %	< 0.13	< 0.12	< 0.12	< 0.12	< 0.12
3 %	< 0.13	< 0.12	< 0.12	< 0.12	< 0.12
3 %	< 0.13	0.34 ± 0.02	0.18 ± 0.04	< 0.12	< 0.12
3.5 %	< 0.13	0.13 ± 0.01	< 0.12	< 0.12	< 0.12
3.5 %	< 0.13	0.23 ± 0.06	< 0.12	< 0.12	< 0.12
5 %	< 0.13	< 0.12	< 0.12	< 0.12	< 0.12
5 %	0.21 ± 0.11	0.19 ± 0.08	< 0.12	< 0.12	< 0.12
10 %	0.30 ± 0.06	2.96 ± 0.13	< 0.12	< 0.12	< 0.12
10 %	0.57 ± 0.16	3.52 ± 0.11	1.64 ± 0.06	< 0.12	< 0.12

Table A-8c. Inductively Coupled Plasma-Mass Spectrometry Data from the Primary Adsorption Isotherm Experiment: Hydroxyapatite (1 of 4)

Weight % of Hydroxyapatite	Chromium µg/L	Manganese µg/L	Iron µg/L	Copper µg/L	Zinc µg/L
0.5 %	<0.2	2.8 ± 0.03	42.7 ± 5.2	1.04 ± 0.05	8.32 ± 0.27
0.5 %	<0.2	2.8 ± 0.03	19.4 ± 0.3	17.44 ± 0.10	<1.4
1 %	0.58 ± 0.02	2.1 ± 0.02	25.1 ± 2.7	0.73 ± 0.05	7.95 ± 0.22
1 %	0.74 ± 0.06	2.3 ± 0.04	28.2 ± 6.4	0.65 ± 0.03	<1.4
1.5 %	1.07 ± 0.02	1.84 ± 0.03	37.3 ± 3.4	1.24 ± 0.04	3.36 ± 0.05
1.5 %	1.15 ± 0.05	1.53 ± 0.01	62.0 ± 1.6	0.66 ± 0.02	2.57 ± 0.11
2 %	1.30 ± 0.03	1.77 ± 0.04	30.0 ± 3.4	26.55 ± 0.52	<1.4
2 %	1.43 ± 0.04	1.57 ± 0.02	37.9 ± 3.4	1.04 ± 0.01	<1.4
2.25 %	1.83 ± 0.09	1.52 ± 0.02	39.7 ± 7.3	<0.5	<1.4
2.25 %	1.86 ± 0.06	1.52 ± 0.06	45.9 ± 6.1	0.94 ± 0.03	<1.4
2.5 %	2.35 ± 0.04	1.10 ± 0.04	48.9 ± 7.4	0.73 ± 0.03	3.15 ± 0.15
2.5 %	2.20 ± 0.05	1.32 ± 0.02	51.4 ± 4.7	0.76 ± 0.04	2.64 ± 0.07
3 %	2.61 ± 0.04	1.24 ± 0.03	52.9 ± 6.2	1.34 ± 0.03	12.78 ± 0.38
3 %	2.69 ± 0.08	1.18 ± 0.03	55.9 ± 5.1	0.70 ± 0.03	2.92 ± 0.04
3.5 %	3.09 ± 0.11	1.04 ± 0.04	59.7 ± 3.5	0.59 ± 0.03	<1.4
3.5 %	2.98 ± 0.02	1.24 ± 0.00	84.2 ± 8.1	1.85 ± 0.08	3.08 ± 0.13
5 %	3.99 ± 0.07	0.99 ± 0.03	51.8 ± 4.6	<0.5	<1.4
5 %	4.21 ± 0.14	1.01 ± 0.03	58.5 ± 4.2	5.13 ± 0.08	10.04 ± 0.06
10 %	7.16 ± 0.11	0.73 ± 0.01	86.2 ± 5.7	<0.5	<1.4
10 %	7.53 ± 0.06	0.71 ± 0.04	80.9 ± 4.4	2.65 ± 0.01	1.59 ± 0.06
Hydroxyapatite	**µmol/L**	**µmol/L**	**µmol/L**	**µmol/L**	**µmol/L**
0.5 %	< 3.8	50.3 ± 0.5	765 ± 93	16.4 ± 0.8	127 ± 4
0.5 %	< 3.8	51.3 ± 0.6	348 ± 5	274.5 ± 1.6	< 21
1 %	11.2 ± 0.3	39.0 ± 0.4	449 ± 48	11.5 ± 0.7	122 ± 3
1 %	14.2 ± 1.1	41.3 ± 0.7	506 ± 114	10.3 ± 0.4	< 21
1.5 %	20.6 ± 0.4	33.6 ± 0.5	668 ± 62	19.5 ± 0.6	51 ± 1
1.5 %	22.1 ± 1.1	27.9 ± 0.2	1110 ± 28	10.4 ± 0.3	39 ± 2
2 %	25.1 ± 0.6	32.2 ± 0.7	538 ± 60	417.9 ± 8.2	< 21
2 %	27.4 ± 0.7	28.6 ± 0.4	678 ± 60	16.4 ± 0.2	< 21
2.25 %	35.1 ± 1.7	27.7 ± 0.4	710 ± 130	< 8.0	< 21
2.25 %	35.9 ± 1.2	27.8 ± 1.0	822 ± 109	14.9 ± 0.5	< 21
2.5 %	45.2 ± 0.8	20.1 ± 0.8	876 ± 132	11.6 ± 0.5	48 ± 2
2.5 %	42.4 ± 0.9	24.1 ± 0.4	920 ± 85	11.9 ± 0.6	40 ± 1
3 %	50.1 ± 0.8	22.6 ± 0.6	947 ± 111	21.1 ± 0.5	195 ± 6
3 %	51.8 ± 1.6	21.6 ± 0.6	1002 ± 92	11.1 ± 0.5	45 ± 1
3.5 %	59.5 ± 2.1	18.9 ± 0.7	1069 ± 62	9.3 ± 0.5	< 21
3.5 %	57.3 ± 0.5	22.6 ± 0.1	1507 ± 145	29.2 ± 1.3	47 ± 2
5 %	76.7 ± 1.3	18.0 ± 0.5	928 ± 82	< 8.0	< 21
5 %	81.0 ± 2.6	18.3 ± 0.6	1047 ± 74	80.7 ± 1.2	154 ± 1
10 %	137.7 ± 2.2	13.3 ± 0.2	1543 ± 101	< 8.0	< 21
10 %	144.8 ± 1.2	13.0 ± 0.7	1449 ± 79	41.8 ± 0.1	24 ± 1

Table A-8c. Inductively Coupled Plasma-Mass Spectrometry Data from the Primary Adsorption Isotherm Experiment: Hydroxyapatite (2 of 4)

Weight % of Hydroxyapatite	Cesium µg/L	Strontium µg/L	Barium µg/L	Arsenic µg/L	Lead µg/L
0.5 %	0.024 ± 0.001	58.7 ± 0.7	11.0 ± 0.17	0.37 ± 0.02	<0.1
0.5 %	0.013 ± 0.003	58.6 ± 0.1	10.5 ± 0.11	0.41 ± 0.03	<0.1
1 %	0.017 ± 0.001	57.0 ± 0.3	11.1 ± 0.05	0.29 ± 0.03	<0.1
1 %	<0.01	60.3 ± 0.7	11.1 ± 0.06	0.35 ± 0.08	<0.1
1.5 %	<0.01	57.9 ± 0.2	11.5 ± 0.04	0.25 ± 0.03	<0.1
1.5 %	<0.01	54.3 ± 0.3	11.5 ± 0.13	0.23 ± 0.03	<0.1
2 %	<0.01	55.8 ± 0.2	11.4 ± 0.10	0.27 ± 0.01	<0.1
2 %	<0.01	58.5 ± 0.4	12.0 ± 0.05	0.19 ± 0.02	<0.1
2.25 %	<0.01	59.4 ± 0.4	12.1 ± 0.08	0.17 ± 0.04	<0.1
2.25 %	<0.01	62.2 ± 0.3	12.6 ± 0.07	0.19 ± 0.02	<0.1
2.5 %	<0.01	54.1 ± 0.7	11.7 ± 0.09	0.19 ± 0.04	<0.1
2.5 %	<0.01	58.4 ± 0.1	12.7 ± 0.20	0.16 ± 0.04	<0.1
3 %	<0.01	58.0 ± 0.2	12.4 ± 0.07	0.16 ± 0.00	<0.1
3 %	<0.01	57.2 ± 0.4	12.3 ± 0.15	0.15 ± 0.04	<0.1
3.5 %	<0.01	55.7 ± 0.7	12.3 ± 0.11	0.15 ± 0.05	0.64 ± 0.01
3.5 %	0.018 ± 0.004	55.5 ± 0.1	12.2 ± 0.13	0.16 ± 0.05	<0.1
5 %	<0.01	55.9 ± 0.3	11.3 ± 0.08	0.13 ± 0.04	0.94 ± 0.03
5 %	<0.01	51.4 ± 0.4	11.0 ± 0.04	0.14 ± 0.05	1.44 ± 0.03
10 %	<0.01	51.5 ± 0.3	12.3 ± 0.05	0.12 ± 0.03	<0.1
10 %	<0.01	50.9 ± 0.9	11.2 ± 0.09	0.16 ± 0.02	<0.1
Hydroxyapatite	**µmol/L**	**µmol/L**	**µmol/L**	**µmol/L**	**µmol/L**
0.5 %	0.18 ± 0.01	670 ± 8	79.9 ± 1.2	5.0 ± 0.3	< 0.5
0.5 %	0.09 ± 0.02	669 ± 1	76.7 ± 0.8	5.4 ± 0.4	< 0.5
1 %	0.13 ± 0.01	651 ± 4	80.7 ± 0.3	3.9 ± 0.4	< 0.5
1 %	< 0.08	688 ± 8	80.7 ± 0.4	4.7 ± 1.0	< 0.5
1.5 %	< 0.08	661 ± 2	83.9 ± 0.3	3.3 ± 0.5	< 0.5
1.5 %	< 0.08	620 ± 3	84.0 ± 0.9	3.1 ± 0.5	< 0.5
2 %	< 0.08	637 ± 3	83.0 ± 0.7	3.5 ± 0.1	< 0.5
2 %	< 0.08	668 ± 5	87.1 ± 0.4	2.5 ± 0.3	< 0.5
2.25 %	< 0.08	678 ± 5	88.0 ± 0.6	2.3 ± 0.5	< 0.5
2.25 %	< 0.08	710 ± 4	92.0 ± 0.5	2.5 ± 0.3	< 0.5
2.5 %	< 0.08	617 ± 8	85.2 ± 0.6	2.5 ± 0.5	< 0.5
2.5 %	< 0.08	667 ± 1	92.1 ± 1.4	2.1 ± 0.5	< 0.5
3 %	< 0.08	662 ± 3	90.4 ± 0.5	2.1 ± 0.0	< 0.5
3 %	< 0.08	653 ± 4	89.6 ± 1.1	2.0 ± 0.5	< 0.5
3.5 %	< 0.08	636 ± 8	89.7 ± 0.8	2.0 ± 0.6	3.11 ± 0.05
3.5 %	0.13 ± 0.03	633 ± 1	88.8 ± 0.9	2.1 ± 0.6	< 0.5
5 %	< 0.08	637 ± 4	82.5 ± 0.6	1.8 ± 0.6	4.56 ± 0.12
5 %	< 0.08	586 ± 5	80.1 ± 0.3	1.9 ± 0.6	6.96 ± 0.16
10 %	< 0.08	588 ± 4	89.5 ± 0.3	1.6 ± 0.4	< 0.5
10 %	< 0.08	581 ± 10	81.7 ± 0.6	2.1 ± 0.2	< 0.5

Table A-8c. Inductively Coupled Plasma-Mass Spectrometry Data from the Primary Adsorption Isotherm Experiment: Hydroxyapatite (3 of 4)

Weight % of Hydroxyapatite	Yttrium µg/L	Lanthanum µg/L	Praeseodymium µg/L	Samarium µg/L	Europium µg/L
0.5 %	0.07 ± 0.004	<0.05	<0.05	<0.05	<0.05
0.5 %	<0.06	<0.05	<0.05	<0.05	<0.05
1 %	<0.06	<0.05	<0.05	<0.05	0.13 ± 0.03
1 %	<0.06	<0.05	<0.05	<0.05	<0.05
1.5 %	<0.06	<0.05	<0.05	<0.05	<0.05
1.5 %	<0.06	<0.05	<0.05	<0.05	<0.05
2 %	<0.06	0.14 ± 0.03	<0.05	<0.05	0.28 ± 0.03
2 %	<0.06	<0.05	<0.05	<0.05	0.31 ± 0.03
2.25 %	<0.06	<0.05	<0.05	<0.05	0.19 ± 0.03
2.25 %	<0.06	<0.05	<0.05	<0.05	<0.05
2.5 %	0.19 ± 0.07	0.11 ± 0.02	<0.05	<0.05	<0.05
2.5 %	<0.06	<0.05	<0.05	<0.05	<0.05
3 %	<0.06	<0.05	<0.05	<0.05	<0.05
3 %	<0.06	<0.05	<0.05	<0.05	<0.05
3.5 %	<0.06	<0.05	<0.05	<0.05	<0.05
3.5 %	<0.06	<0.05	<0.05	<0.05	0.08 ± 0.01
5 %	<0.06	<0.05	<0.05	<0.05	0.22 ± 0.02
5 %	<0.06	0.07 ± 0.02	<0.05	<0.05	<0.05
10 %	<0.06	<0.05	<0.05	<0.05	0.31 ± 0.01
10 %	<0.06	<0.05	<0.05	<0.05	<0.05
Hydroxyapatite	**µmol/L**	**µmol/L**	**µmol/L**	**µmol/L**	**µmol/L**
0.5 %	0.84 ± 0.05	< 0.4	< 0.35	< 0.3	< 0.33
0.5 %	< 0.7	< 0.4	< 0.35	< 0.3	< 0.33
1 %	< 0.7	< 0.4	< 0.35	< 0.3	0.88 ± 0.17
1 %	< 0.7	< 0.4	< 0.35	< 0.3	< 0.33
1.5 %	< 0.7	< 0.4	< 0.35	< 0.3	< 0.33
1.5 %	< 0.7	< 0.4	< 0.35	< 0.3	< 0.33
2 %	< 0.7	1.0 ± 0.2	< 0.35	< 0.3	1.84 ± 0.17
2 %	< 0.7	< 0.4	< 0.35	< 0.3	2.06 ± 0.21
2.25 %	< 0.7	< 0.4	< 0.35	< 0.3	1.27 ± 0.19
2.25 %	< 0.7	< 0.4	< 0.35	< 0.3	< 0.33
2.5 %	2.1 ± 0.7	0.8 ± 0.1	< 0.35	< 0.3	< 0.33
2.5 %	< 0.7	< 0.4	< 0.35	< 0.3	< 0.33
3 %	< 0.7	< 0.4	< 0.35	< 0.3	< 0.33
3 %	< 0.7	< 0.4	< 0.35	< 0.3	< 0.33
3.5 %	< 0.7	< 0.4	< 0.35	< 0.3	< 0.33
3.5 %	< 0.7	< 0.4	< 0.35	< 0.3	0.50 ± 0.09
5 %	< 0.7	< 0.4	< 0.35	< 0.3	1.46 ± 0.12
5 %	< 0.7	0.5 ± 0.1	< 0.35	< 0.3	< 0.33
10 %	< 0.7	< 0.4	< 0.35	< 0.3	2.02 ± 0.10
10 %	< 0.7	< 0.4	< 0.35	< 0.3	< 0.33

Table A-8c. Inductively Coupled Plasma-Mass Spectrometry Data from the Primary Adsorption Isotherm Experiment: Hydroxyapatite (4 of 4)

Weight % of Hydroxyapatite	Gadolinium µg/L	Dysprosium µg/L	Holmium µg/L	Erbium µg/L	Ytterbium µg/L
0.5 %	<0.02	<0.02	<0.02	<0.02	<0.02
0.5 %	0.09 ± 0.01	0.24 ± 0.01	<0.02	<0.02	<0.02
1 %	<0.02	0.13 ± 0.01	<0.02	<0.02	<0.02
1 %	<0.02	<0.02	<0.02	<0.02	<0.02
1.5 %	<0.02	<0.02	0.03 ± 0.01	<0.02	<0.02
1.5 %	<0.02	<0.02	<0.02	<0.02	<0.02
2 %	<0.02	<0.02	<0.02	<0.02	<0.02
2 %	<0.02	<0.02	<0.02	<0.02	<0.02
2.25 %	<0.02	<0.02	<0.02	<0.02	<0.02
2.25 %	<0.02	0.04 ± 0.02	<0.02	<0.02	<0.02
2.5 %	<0.02	0.04 ± 0.01	0.05 ± 0.01	<0.02	<0.02
2.5 %	<0.02	<0.02	<0.02	<0.02	<0.02
3 %	<0.02	<0.02	<0.02	<0.02	<0.02
3 %	<0.02	<0.02	<0.02	<0.02	<0.02
3.5 %	<0.02	0.02 ± 0.01	<0.02	<0.02	<0.02
3.5 %	<0.02	0.05 ± 0.01	<0.02	<0.02	<0.02
5 %	<0.02	<0.02	<0.02	<0.02	<0.02
5 %	0.08 ± 0.01	0.04 ± 0.02	0.02 ± 0.00	<0.02	<0.02
10 %	<0.02	<0.02	<0.02	<0.02	<0.02
10 %	<0.02	<0.02	<0.02	<0.02	<0.02
Hydroxyapatite	**µmol/L**	**µmol/L**	**µmol/L**	**µmol/L**	**µmol/L**
0.5 %	< 0.13	< 0.12	< 0.12	< 0.12	< 0.12
0.5 %	0.57 ± 0.06	1.45 ± 0.05	< 0.12	< 0.12	< 0.12
1 %	< 0.13	0.77 ± 0.06	< 0.12	< 0.12	< 0.12
1 %	< 0.13	< 0.12	< 0.12	< 0.12	< 0.12
1.5 %	< 0.13	< 0.12	0.19 ± 0.03	< 0.12	< 0.12
1.5 %	< 0.13	< 0.12	< 0.12	< 0.12	< 0.12
2 %	< 0.13	< 0.12	< 0.12	< 0.12	< 0.12
2 %	< 0.13	< 0.12	< 0.12	< 0.12	< 0.12
2.25 %	< 0.13	< 0.12	< 0.12	< 0.12	< 0.12
2.25 %	< 0.13	0.23 ± 0.09	< 0.12	< 0.12	< 0.12
2.5 %	< 0.13	0.22 ± 0.05	0.30 ± 0.04	< 0.12	< 0.12
2.5 %	< 0.13	< 0.12	< 0.12	< 0.12	< 0.12
3 %	< 0.13	< 0.12	< 0.12	< 0.12	< 0.12
3 %	< 0.13	< 0.12	< 0.12	< 0.12	< 0.12
3.5 %	< 0.13	0.15 ± 0.07	< 0.12	< 0.12	< 0.12
3.5 %	< 0.13	0.33 ± 0.04	< 0.12	< 0.12	< 0.12
5 %	< 0.13	< 0.12	< 0.12	< 0.12	< 0.12
5 %	0.53 ± 0.06	0.25 ± 0.10	0.13 ± 0.03	< 0.12	< 0.12
10 %	< 0.13	< 0.12	< 0.12	< 0.12	< 0.12
10 %	< 0.13	< 0.12	< 0.12	< 0.12	< 0.12

Table A-8d. Inductively Coupled Plasma-Mass Spectrometry Data from the Primary Adsorption Isotherm Experiment: Clinoptilolite (1 of 4)

Weight % of Clinoptilolite	Chromium µg/L	Manganese µg/L	Iron µg/L	Copper µg/L	Zinc µg/L
0.5 %	<0.2	3.9 ± 0.1	31.5 ± 3.3	1.68 ± 0.15	<1.4
0.5 %	<0.2	5.1 ± 0.1	58.2 ± 0.7	7.79 ± 0.02	1.9 ± 0.1
1 %	<0.2	4.4 ± 0.0	59.4 ± 2.2	0.93 ± 0.07	<1.4
1 %	<0.2	5.5 ± 0.1	78.3 ± 4.9	<0.50	<1.4
1.5 %	<0.2	2.5 ± 0.0	13.2 ± 1.4	<0.50	<1.4
1.5 %	<0.2	2.8 ± 0.0	21.8 ± 3.8	0.81 ± 0.05	12.2 ± 0.3
2 %	0.25 ± 0.04	6.7 ± 0.1	118 ± 3.8	<0.50	3.1 ± 0.3
2 %	<0.2	4.2 ± 0.1	58.3 ± 4.1	<0.50	<1.4
2.25 %	<0.2	2.7 ± 0.0	27.1 ± 3.5	<0.50	<1.4
2.25 %	<0.2	8.7 ± 0.1	175 ± 5.1	0.57 ± 0.04	<1.4
2.5 %	0.75 ± 0.04	40.6 ± 0.2	1089 ± 34	0.71 ± 0.02	1.5 ± 0.03
2.5 %	<0.2	2.4 ± 0.0	31.5 ± 3.0	<0.50	2.4 ± 0.3
3 %	<0.2	2.9 ± 0.0	48.0 ± 3.7	0.90 ± 0.07	<1.4
3 %	<0.2	5.6 ± 0.0	102 ± 4.0	14.26 ± 0.18	<1.4
3.5 %	<0.2	3.80 ± 0.0	67.9 ± 1.2	<0.50	<1.4
3.5 %	1.14 ± 0.03	7.75 ± 0.1	206 ± 3.3	1.31 ± 0.03	<1.4
5 %	<0.2	1.24 ± 0.0	13.7 ± 3.3	<0.50	<1.4
5 %	<0.2	1.76 ± 0.0	19.6 ± 1.1	<0.50	<1.4
10 %	<2.0	16.8 ± 0.3	376 ± 38	6.17 ± 0.31	127 ± 2
10 %	<2.0	19.7 ± 0.2	497 ± 23	<0.50	<1.4
Clinoptilolite	µmol/L	µmol/L	µmol/L	µmol/L	µmol/L
0.5 %	<3.8	70.4 ± 1.5	564 ± 59	26.5 ± 2.4	<21
0.5 %	<3.8	92.6 ± 2.2	1041 ± 13	122.6 ± 0.3	29 ± 2
1 %	<3.8	80.4 ± 0.8	1063 ± 40	14.7 ± 1.1	<21
1 %	<3.8	99.4 ± 2.1	1401 ± 88	<8.0	<21
1.5 %	<3.8	45.6 ± 0.3	236 ± 26	<8.0	<21
1.5 %	<3.8	51.4 ± 0.7	391 ± 69	12.7 ± 0.7	186 ± 4
2 %	4.8 ± 0.7	121.5 ± 1.5	2117 ± 69	<8.0	48 ± 5
2 %	<3.8	77.0 ± 1.5	1044 ± 74	<8.0	<21
2.25 %	<3.8	48.8 ± 0.7	486 ± 62	<8.0	<21
2.25 %	<3.8	158.5 ± 1.1	3133 ± 92	9.0 ± 0.6	<21
2.5 %	14.4 ± 0.7	739.1 ± 4.0	19508 ± 609	11.1 ± 0.3	23 ± 0
2.5 %	<3.8	43.1 ± 0.3	564 ± 54	<8.0	37 ± 4
3 %	<3.8	52.1 ± 0.8	860 ± 66	14.2 ± 1.1	<21
3 %	<3.8	101.7 ± 0.7	1831 ± 72	224.3 ± 2.8	<21
3.5 %	<3.8	69.2 ± 0.5	1216 ± 21	<8.0	<21
3.5 %	22.0 ± 0.5	141.1 ± 1.6	3680 ± 59	20.6 ± 0.5	<21
5 %	<3.8	22.5 ± 0.9	246 ± 60	<8.0	<21
5 %	<3.8	32.1 ± 0.8	350 ± 19	<8.0	<21
10 %	<3.8	305.6 ± 6.0	6728 ± 675	97.0 ± 4.9	1950 ± 32
10 %	<3.8	359.4 ± 4.4	8896 ± 409	<8.0	<21

Table A-8d. Inductively Coupled Plasma-Mass Spectrometry Data from the Primary Adsorption Isotherm Experiment: Clinoptilolite (2 of 4)

Weight % of Clinoptilolite	Cesium µg/L	Strontium µg/L	Barium µg/L	Arsenic µg/L	Lead µg/L
0.5 %	<0.01	30.9 ± 0.4	7.5 ± 0.1	0.76 ± 0.05	0.25 ± 0.01
0.5 %	0.15 ± 0.002	32 ± 0.3	8.0 ± 0.1	0.62 ± 0.04	<0.1
1 %	<0.01	20.1 ± 0.1	5.5 ± 0.1	0.84 ± 0.04	0.23 ± 0.004
1 %	0.64 ± 0.02	21 ± 0.3	6.2 ± 0.1	0.86 ± 0.07	<0.1
1.5 %	0.12 ± 0.01	20.4 ± 0.1	4.9 ± 0.1	0.78 ± 0.10	<0.1
1.5 %	0.09 ± 0.003	17.1 ± 0.1	4.6 ± 0.01	0.97 ± 0.14	0.25 ± 0.01
2 %	<0.01	17.5 ± 0.1	5.5 ± 0.05	1.06 ± 0.04	<0.1
2 %	<0.01	16.1 ± 0.2	4.3 ± 0.1	0.94 ± 0.08	<0.1
2.25 %	<0.01	13.0 ± 0.1	3.2 ± 0.02	0.77 ± 0.05	0.52 ± 0.005
2.25 %	<0.01	15.2 ± 0.1	4.9 ± 0.04	0.92 ± 0.05	0.35 ± 0.02
2.5 %	<0.01	9.7 ± 0.3	10.7 ± 0.1	1.04 ± 0.10	0.42 ± 0.01
2.5 %	<0.01	9.1 ± 0.1	2.4 ± 0.04	0.85 ± 0.02	<0.1
3 %	<0.01	8.6 ± 0.1	2.3 ± 0.03	1.00 ± 0.06	0.16 ± 0.01
3 %	<0.01	9.4 ± 0.1	4.1 ± 0.05	0.86 ± 0.08	<0.1
3.5 %	0.03 ± 0.02	7.3 ± 0.1	2.5 ± 0.02	1.02 ± 0.05	<0.1
3.5 %	0.06 ± 0.01	7.5 ± 0.03	3.5 ± 0.03	1.07 ± 0.05	<0.1
5 %	<0.01	0.4 ± 0.02	0.4 ± 0.00	0.16 ± 0.04	<0.1
5 %	<0.01	0.4 ± 0.01	0.4 ± 0.01	0.11 ± 0.02	<0.1
10 %	na	5 ± 0.2	7.9 ± 0.2	3.66 ± 0.99	5.88 ± 0.13
10 %	<0.01	3.5 ± 0.2	5.5 ± 0.1	4.15 ± 0.29	<0.1
Clinoptilolite	**µmol/L**	**µmol/L**	**µmol/L**	**µmol/L**	**µmol/L**
0.5 %	< 0.08	353 ± 4	54.5 ± 0.8	10.1 ± 0.7	1.2 ± 0.1
0.5 %	1.10 ± 0.02	360 ± 4	57.9 ± 0.5	8.2 ± 0.5	< 0.5
1 %	< 0.08	229 ± 1	40.2 ± 0.4	11.2 ± 0.6	1.1 ± 0.02
1 %	4.85 ± 0.15	237 ± 3	45.2 ± 0.5	11.5 ± 1.0	< 0.5
1.5 %	0.91 ± 0.06	233 ± 1	35.8 ± 0.4	10.4 ± 1.4	< 0.5
1.5 %	0.69 ± 0.03	195 ± 1	33.9 ± 0.1	13.0 ± 1.8	1.2 ± 0.04
2 %	< 0.08	199 ± 1	40.2 ± 0.3	14.2 ± 0.5	< 0.5
2 %	< 0.08	184 ± 3	31.5 ± 0.9	12.6 ± 1.1	< 0.5
2.25 %	< 0.08	148 ± 1	23.3 ± 0.1	10.3 ± 0.6	2.5 ± 0.02
2.25 %	< 0.08	174 ± 1	36.0 ± 0.3	12.3 ± 0.7	1.7 ± 0.1
2.5 %	< 0.08	110 ± 3	77.8 ± 0.7	13.8 ± 1.3	2.0 ± 0.04
2.5 %	< 0.08	104 ± 1	17.5 ± 0.3	11.3 ± 0.3	< 0.5
3 %	< 0.08	98 ± 1	16.8 ± 0.2	13.3 ± 0.7	0.8 ± 0.1
3 %	< 0.08	107 ± 1	30.0 ± 0.4	11.5 ± 1.1	< 0.5
3.5 %	0.22 ± 0.19	83 ± 1	18.2 ± 0.2	13.6 ± 0.7	< 0.5
3.5 %	0.44 ± 0.07	86 ± 0	25.6 ± 0.2	14.3 ± 0.7	< 0.5
5 %	< 0.08	5.1 ± 0.2	2.9 ± 0.0	2.2 ± 0.5	< 0.5
5 %	< 0.08	5.1 ± 0.2	3.1 ± 0.1	1.5 ± 0.3	< 0.5
10 %	0.00 ± 0.00	55 ± 2	57.2 ± 1.4	49 ± 13	28.4 ± 0.6
10 %	< 0.08	40 ± 3	39.8 ± 0.8	55 ± 4	< 0.5

Table A-8d. Inductively Coupled Plasma-Mass Spectrometry Data from the Primary Adsorption Isotherm Experiment: Clinoptilolite (3 of 4)

Weight % of	Yttrium			Lanthanum			Praeseodymium			Samarium			Europium		
Clinoptilolite	µg/L			µg/L			µg/L			µg/L			µg/L		
0.5 %	0.21	±	0.05	0.30	±	0.04	<0.05			<0.05			0.05	±	0.01
0.5 %	0.51	±	0.04	0.69	±	0.08	0.07	±	0.01	0.08	±	0.03	0.13	±	0.01
1 %	0.69	±	0.05	1.07	±	0.09	0.11	±	0.01	0.12	±	0.01	0.05	±	0.01
1 %	0.85	±	0.08	1.21	±	0.03	0.13	±	0.01	0.08	±	0.02	<0.05		
1.5 %	0.15	±	0.03	0.25	±	0.01	<0.05			<0.05			<0.05		
1.5 %	0.22	±	0.03	0.27	±	0.05	<0.05			<0.05			<0.05		
2 %	0.82	±	0.08	1.70	±	0.07	0.14	±	0.02	0.13	±	0.03	<0.05		
2 %	0.47	±	0.06	0.88	±	0.11	0.08	±	0.02	0.13	±	0.02	<0.05		
2.25 %	0.27	±	0.04	0.53	±	0.04	<0.05			<0.05			<0.05		
2.25 %	1.17	±	0.01	3.10	±	0.12	0.21	±	0.02	0.20	±	0.03	<0.05		
2.5 %	4.26	±	0.08	10.12	±	1.04	1.03	±	0.02	0.74	±	0.10	<0.05		
2.5 %	0.19	±	0.04	0.14	±	0.03	<0.05			<0.05			<0.05		
3 %	0.23	±	0.02	0.29	±	0.01	0.06	±	0.01	<0.05			<0.05		
3 %	0.39	±	0.01	0.43	±	0.08	0.13	±	0.01	0.12	±	0.02	0.09	±	0.002
3.5 %	0.25	±	0.01	0.28	±	0.03	0.08	±	0.01	0.06	±	0.02	<0.05		
3.5 %	0.51	±	0.01	0.69	±	0.06	0.21	±	0.01	0.14	±	0.06	<0.05		
5 %	0.12	±	0.01	0.17	±	0.01	0.06	±	0.02	0.08	±	0.04	0.13	±	0.02
5 %	0.09	±	0.01	0.09	±	0.01	<0.05			<0.05			<0.05		
10 %	4.10	±	0.51	92.15	±	2.93	0.94	±	0.22	0.58	±	0.13	<0.5		
10 %	4.61	±	0.23	11.35	±	1.38	0.92	±	0.18	1.10	±	0.26	0.91	±	0.07
Clinoptilolite	µmol/L			µmol/L			µmol/L			µmol/L			µmol/L		
0.5 %	2.4	±	0.6	2.1	±	0.3	< 0.4			< 0.3			0.35	±	0.04
0.5 %	5.7	±	0.5	5.0	±	0.6	0.5	±	0.1	0.5	±	0.2	0.84	±	0.05
1 %	7.7	±	0.5	7.7	±	0.7	0.8	±	0.1	0.8	±	0.1	0.35	±	0.04
1 %	9.5	±	0.9	8.7	±	0.2	0.9	±	0.1	0.6	±	0.2	< 0.33		
1.5 %	1.7	±	0.3	1.8	±	0.1	< 0.4			< 0.3			< 0.33		
1.5 %	2.5	±	0.4	1.9	±	0.4	< 0.4			< 0.3			< 0.33		
2 %	9.2	±	0.9	12.2	±	0.5	1.0	±	0.2	0.9	±	0.2	< 0.33		
2 %	5.3	±	0.7	6.3	±	0.8	0.6	±	0.2	0.9	±	0.2	< 0.33		
2.25 %	3.0	±	0.4	3.8	±	0.3	< 0.4			< 0.3			< 0.33		
2.25 %	13.2	±	0.2	22.3	±	0.9	1.5	±	0.2	1.3	±	0.2	< 0.33		
2.5 %	48.0	±	0.9	72.8	±	7.5	7.3	±	0.2	5.0	±	0.6	< 0.33		
2.5 %	2.1	±	0.4	1.0	±	0.2	< 0.4			< 0.3			< 0.33		
3 %	2.6	±	0.2	2.1	±	0.1	0.4	±	0.1	< 0.3			< 0.33		
3 %	4.4	±	0.1	3.1	±	0.6	0.9	±	0.1	0.8	±	0.1	0.58	±	0.01
3.5 %	2.8	±	0.1	2.0	±	0.2	0.6	±	0.1	0.4	±	0.1	< 0.33		
3.5 %	5.8	±	0.1	5.0	±	0.4	1.5	±	0.0	0.9	±	0.4	< 0.33		
5 %	1.3	±	0.1	1.2	±	0.1	0.4	±	0.1	0.6	±	0.2	0.86	±	0.11
5 %	1.0	±	0.2	0.6	±	0.0	< 0.4			< 0.3			< 0.33		
10 %	46.2	±	5.8	663.4	±	21.1	6.7	±	1.6	3.9	±	0.9	< 0.33		
10 %	51.8	±	2.6	81.7	±	9.9	6.5	±	1.3	7.3	±	1.8	6.00	±	0.49

Table A-8d. Inductively Coupled Plasma-Mass Spectrometry Data from the Primary Adsorption Isotherm Experiment: Clinoptilolite (4 of 4)

Weight % of Clinoptilolite	Gadolinium µg/L	Dysprosium µg/L	Holmium µg/L	Erbium µg/L	Ytterbium µg/L
0.5 %	<0.02	0.07 ± 0.01	0.02 ± 0.002	<0.02	<0.02
0.5 %	0.11 ± 0.03	0.06 ± 0.004	0.02 ± 0.01	0.03 ± 0.003	<0.02
1 %	0.12 ± 0.04	0.14 ± 0.01	0.05 ± 0.001	0.05 ± 0.02	0.03 ± 0.01
1 %	0.13 ± 0.004	0.17 ± 0.01	0.04 ± 0.01	0.06 ± 0.02	0.05 ± 0.02
1.5 %	0.03 ± 0.03	0.06 ± 0.02	<0.02	<0.02	<0.02
1.5 %	0.06 ± 0.04	0.06 ± 0.04	<0.02	0.03 ± 0.01	<0.02
2 %	0.11 ± 0.06	0.09 ± 0.01	0.03 ± 0.01	0.06 ± 0.02	0.07 ± 0.02
2 %	0.06 ± 0.03	0.06 ± 0.01	0.02 ± 0.01	0.03 ± 0.002	<0.02
2.25 %	0.05 ± 0.01	0.08 ± 0.01	<0.02	<0.02	<0.02
2.25 %	0.19 ± 0.05	0.21 ± 0.02	0.06 ± 0.01	0.09 ± 0.02	0.13 ± 0.03
2.5 %	1.03 ± 0.12	0.63 ± 0.02	0.17 ± 0.005	0.48 ± 0.02	0.46 ± 0.11
2.5 %	<0.02	0.04 ± 0.01	<0.02	<0.02	<0.02
3 %	0.08 ± 0.03	0.11 ± 0.02	0.05 ± 0.003	0.04 ± 0.01	0.04 ± 0.04
3 %	0.09 ± 0.005	0.06 ± 0.03	0.02 ± 0.01	0.07 ± 0.02	0.04 ± 0.04
3.5 %	0.05 ± 0.03	0.09 ± 0.01	0.03 ± 0.000	0.05 ± 0.01	<0.02
3.5 %	0.14 ± 0.01	0.09 ± 0.01	0.05 ± 0.01	0.12 ± 0.02	0.06 ± 0.04
5 %	0.04 ± 0.01	0.12 ± 0.005	0.09 ± 0.01	0.03 ± 0.02	<0.02
5 %	<0.02	0.04 ± 0.01	<0.02	<0.02	<0.02
10 %	0.69 ± 0.46	0.87 ± 0.23	<0.2	0.26 ± 0.08	0.20 ± 0.03
10 %	0.60 ± 0.28	11.17 ± 0.66	<0.2	0.30 ± 0.19	<0.2
Clinoptilolite	**µmol/L**	**µmol/L**	**µmol/L**	**µmol/L**	**µmol/L**
0.5 %	< 0.1	0.43 ± 0.06	0.13 ± 0.01	< 0.12	< 0.12
0.5 %	0.7 ± 0.2	0.36 ± 0.03	0.12 ± 0.04	0.2 ± 0.0	< 0.12
1 %	0.8 ± 0.2	0.84 ± 0.06	0.29 ± 0.01	0.3 ± 0.1	0.15 ± 0.06
1 %	0.8 ± 0.0	1.04 ± 0.07	0.25 ± 0.04	0.3 ± 0.1	0.28 ± 0.09
1.5 %	0.2 ± 0.2	0.34 ± 0.13	< 0.12	< 0.12	< 0.12
1.5 %	0.4 ± 0.3	0.39 ± 0.22	< 0.12	0.2 ± 0.0	< 0.12
2 %	0.7 ± 0.4	0.56 ± 0.07	0.16 ± 0.06	0.3 ± 0.1	0.39 ± 0.13
2 %	0.4 ± 0.2	0.35 ± 0.09	0.13 ± 0.05	0.2 ± 0.0	< 0.12
2.25 %	0.3 ± 0.1	0.47 ± 0.07	< 0.12	< 0.12	< 0.12
2.25 %	1.2 ± 0.3	1.29 ± 0.12	0.35 ± 0.04	0.5 ± 0.1	0.77 ± 0.18
2.5 %	6.5 ± 0.7	3.91 ± 0.14	1.02 ± 0.03	2.9 ± 0.1	2.66 ± 0.61
2.5 %	< 0.1	0.26 ± 0.06	< 0.12	< 0.12	< 0.12
3 %	0.5 ± 0.2	0.67 ± 0.10	0.28 ± 0.02	0.2 ± 0.1	0.26 ± 0.24
3 %	0.6 ± 0.0	0.35 ± 0.18	0.14 ± 0.03	0.4 ± 0.1	0.25 ± 0.23
3.5 %	0.3 ± 0.2	0.53 ± 0.08	0.16 ± 0.00	0.3 ± 0.0	< 0.12
3.5 %	0.9 ± 0.1	0.54 ± 0.08	0.28 ± 0.07	0.7 ± 0.1	0.38 ± 0.25
5 %	0.3 ± 0.1	0.71 ± 0.03	0.56 ± 0.09	0.2 ± 0.1	< 0.12
5 %	< 0.1	0.27 ± 0.03	< 0.12	< 0.12	< 0.12
10 %	4.4 ± 2.9	5.35 ± 1.45	< 0.12	1.5 ± 0.5	1.14 ± 0.16
10 %	3.8 ± 1.8	68.74 ± 4.07	< 0.12	1.8 ± 1.1	< 0.12

Table A-8e. Inductively Coupled Plasma-Mass Spectrometry Data from the Primary Adsorption Isotherm Experiment: Hanford Soil (1 of 4)

Weight % of Hanford Soil	Chromium µg/L			Manganese µg/L			Iron µg/L			Copper µg/L			Zinc µg/L		
100 %	<0.2			4.9	±	0.13	80.0	±	3.1	0.73	±	0.02	<1.4		
100 %	<0.2			4.7	±	0.10	68.2	±	2.6	<0.5			<1.4		
100 %	<0.2			5.5	±	0.05	30.0	±	4.8	0.79	±	0.05	1.69	±	0.06
100 %	<0.2			5.3	±	0.06	34.3	±	4.3	0.82	±	0.04	4.14	±	0.08
100 %	<0.2			0.17	±	0.01	na			0.83	±	0.02	3.36	±	0.11
100 %	<0.2			0.18	±	0.04	75.1	±	18.4	2.68	±	0.78	6.65	±	1.37
100 %	<0.2			0.22	±	0.01	86.4	±	1.8	2.31	±	0.04	2.22	±	0.08
100 %	0.31	±	0.02	0.19	±	0.01	57.2	±	2.3	1.99	±	0.04	1.93	±	0.04
100 %	<0.2			0.19	±	0.02	na			2.00	±	0.04	3.13	±	0.01
Avg. ± Std. Dev.	0.31	±	0.02	2.38	±	2.61	61.6	±	22.2	1.52	±	0.80	3.30	±	1.71

Hanford Soil	µmol/L			µmol/L			µmol/L			µmol/L			µmol/L		
100 %	< 3.8			89.8	±	2.4	1433	±	56	11.5	±	0.4	< 21		
100 %	< 3.8			85.6	±	1.8	1222	±	46	< 8.0			< 21		
100 %	< 3.8			100.3	±	1.0	537	±	85	12.5	±	0.8	26	±	1
100 %	< 3.8			97.1	±	1.0	614	±	77	12.9	±	0.6	63	±	1
100 %	< 3.8			3.0	±	0.1	na			13.1	±	0.4	51	±	2
100 %	< 3.8			3.2	±	0.7	1345	±	330	42.2	±	12.3	102	±	21
100 %	< 3.8			4.0	±	0.1	1548	±	32	36.4	±	0.6	34	±	1
100 %	6.0	±	0.3	3.4	±	0.2	1024	±	41	31.3	±	0.6	29	±	1
100 %	< 3.8			3.5	±	0.3	na			31.5	±	0.7	48	±	0

Table A-8e. Inductively Coupled Plasma-Mass Spectrometry Data from the Primary Adsorption Isotherm Experiment: Hanford Soil (2 of 4)

Weight % of Hanford Soil	Cesium µg/L	Strontium µg/L			Barium µg/L			Arsenic µg/L			Lead µg/L		
100 %	<0.01	55.0	±	0.4	10.8	±	0.08	0.41	±	0.03	<0.1		
100 %	<0.01	56.8	±	0.1	10.5	±	0.12	0.37	±	0.01	<0.1		
100 %	<0.01	57.7	±	0.1	11.2	±	0.13	0.47	±	0.03	<0.1		
100 %	<0.01	61.9	±	0.3	11.9	±	0.01	0.46	±	0.09	0.20	±	0.01
100 %	<0.01	5.0	±	0.1	0.25	±	0.01	<0.03			0.17	±	0.01
100 %	<0.01	6.3	±	1.1	0.54	±	0.08	<0.03			1.54	±	0.32
100 %	<0.01	5.3	±	0.01	0.26	±	0.01	<0.03			0.35	±	0.01
100 %	<0.01	5.4	±	0.04	0.28	±	0.02	<0.03			0.25	±	0.02
100 %	<0.01	5.5	±	0.03	0.30	±	0.01	<0.03			0.51	±	0.01
Avg. ± Std. Dev.	0.01	28.76	±	27.65	5.11	±	5.69	0.43	±	0.05	0.50	±	0.52
Hanford Soil	**µmol/L**	**µmol/L**			**µmol/L**			**µmol/L**			**µmol/L**		
100 %	< 0.08	628	±	4	78.7	±	0.6	5.5	±	0.3	< 0.5		
100 %	< 0.08	648	±	1	76.3	±	0.8	4.9	±	0.2	< 0.5		
100 %	< 0.08	659	±	1	81.7	±	0.9	6.3	±	0.4	< 0.5		
100 %	< 0.08	706	±	4	86.5	±	0.1	6.1	±	1.2	1.0	±	0.0
100 %	< 0.08	57	±	1	1.8	±	0.1	< 0.4			0.8	±	0.0
100 %	< 0.08	72	±	13	4.0	±	0.5	< 0.4			7.4	±	1.6
100 %	< 0.08	61	±	0.12	1.9	±	0.0	< 0.4			1.7	±	0.0
100 %	< 0.08	61	±	0.47	2.0	±	0.1	< 0.4			1.2	±	0.1
100 %	< 0.08	62	±	0.30	2.2	±	0.1	< 0.4			2.5	±	0.1

Table A-8e. Inductively Coupled Plasma-Mass Spectrometry Data from the Primary Adsorption Isotherm Experiment: Hanford Soil (3 of 4)

Weight % of Hanford Soil	Yttrium µg/L			Lanthanum µg/L			Praeseodymium µg/L	Samarium µg/L			Europium µg/L
100 %	<0.06			<0.05			<0.05	<0.05			<0.05
100 %	<0.06			<0.05			<0.05	<0.05			<0.05
100 %	<0.06			<0.05			<0.05	<0.05			<0.05
100 %	0.08	±	0.01	<0.05			<0.05	<0.05			<0.05
100 %	0.09	±	0.02	<0.05			<0.05	<0.05			<0.05
100 %	0.06	±	0.01	0.06	±	0.04	<0.05	0.09	±	0.04	<0.05
100 %	0.06			0.18	±	0.02	<0.05	<0.05			<0.05
100 %	<0.06			0.06	±	0.01	<0.05	<0.05			<0.05
100 %	0.12	±	0.01	0.08	±	0.01	<0.05	<0.05			<0.05
Avg. ± Std. Dev.	0.08	±	0.03	0.10	±	0.06					

Hanford Soil	µmol/L			µmol/L			µmol/L	µmol/L			µmol/L
100 %	< 0.7			< 0.4			< 0.4	< 0.3			< 0.33
100 %	< 0.7			< 0.4			< 0.4	< 0.3			< 0.33
100 %	< 0.7			< 0.4			< 0.4	< 0.3			< 0.33
100 %	0.9	±	0.1	< 0.4			< 0.4	< 0.3			< 0.33
100 %	1.1	±	0.2	< 0.4			< 0.4	< 0.3			< 0.33
100 %	0.7	±	0.1	0.4	±	0.3	< 0.4	0.6	±	0.2	< 0.33
100 %	< 0.7			1.3	±	0.1	< 0.4	< 0.3			< 0.33
100 %	< 0.7			0.4	±	0.1	< 0.4	< 0.3			< 0.33
100 %	1.4	±	0.1	0.6	±	0.1	< 0.4	< 0.3			< 0.33

Table A-8e. Inductively Coupled Plasma-Mass Spectrometry Data from the Primary Adsorption Isotherm Experiment: Hanford Soil (4 of 4)

Weight % of Hanford Soil	Gadolinium µg/L	Dysprosium µg/L	Holmium µg/L	Erbium µg/L	Ytterbium µg/L
100 %	<0.02	<0.02	<0.02	<0.02	<0.02
100 %	<0.02	<0.02	<0.02	<0.02	<0.02
100 %	<0.02	<0.02	<0.02	<0.02	<0.02
100 %	<0.02	0.02 ± 0.01	<0.02	<0.02	<0.02
100 %	0.38 ± 0.05	<0.02	<0.02	<0.02	<0.02
100 %	1.03 ± 0.19	0.05 ± 0.05	0.03 ± 0.01	0.06 ± 0.01	0.06 ± 0.07
100 %	0.26 ± 0.02	0.03 ± 0.00	<0.02	<0.02	<0.02
100 %	0.22 ± 0.04	0.04 ± 0.01	<0.02	<0.02	<0.02
100 %	<0.02	2.01 ± 0.03	0.04 ± 0.01	<0.02	<0.02
Avg. ± Std. Dev.	0.47 ± 0.38	0.43 ± 0.88	0.03 ± 0.00		

Hanford Soil	µmol/L	µmol/L	µmol/L	µmol/L	µmol/L
100 %	< 0.1	< 0.12	< 0.12	< 0.12	< 0.12
100 %	< 0.1	< 0.12	< 0.12	< 0.12	< 0.12
100 %	< 0.1	< 0.12	< 0.12	< 0.12	< 0.12
100 %	< 0.1	0.15 ± 0.04	< 0.12	< 0.12	< 0.12
100 %	2.4 ± 0.3	< 0.12	< 0.12	< 0.12	< 0.12
100 %	6.6 ± 1.2	0.33 ± 0.28	0.20 ± 0.04	0.4 ± 0.0	0.34 ± 0.41
100 %	1.7 ± 0.1	0.19 ± 0.02	< 0.12	< 0.12	< 0.12
100 %	1.4 ± 0.2	0.23 ± 0.04	< 0.12	< 0.12	< 0.12
100 %	< 0.1	12.39 ± 0.17	0.22 ± 0.03	< 0.12	< 0.12

APPENDIX B.

Experiment B: Kinetics of Complexation

Table B-1. Liquid Scintillation Counting of Strontium-90, pH, and Conductivity Data from the Kinetics Experiment

	Time hours	Date of counting	Sr-90 Bq/mL	pCi/L	pH	Conductivity microSi/cm
NC Apatite 1%	1	12/27/95	0.42	11,349	7.88	147
	3	12/27/95	0.40	10,941	8.31	154
	5	12/27/95	0.44	11,882	7.73	140
	10	12/27/95	0.47	12,613	7.79	149
	15	12/27/95	0.52	13,982	6.81	150
	24	12/27/95	0.51	13,845	8.09	155
Bone Char 5%	1	12/27/95	0.29	7,958	9.23	197
	3	12/27/95	0.28	7,488	9.47	195
	5	12/27/95	0.30	8,163	9.26	195
	10	12/27/95	0.24	6,573	9.45	187
	15	12/28/95	0.21	5,619	9.63	200
	24	12/28/95	0.20	5,367	9.50	195
Hydroxyapatite 5%	1	12/28/95	0.33	8,804	7.96	171
	3	12/28/95	0.35	9,518	8.45	168
	5	12/28/95	0.34	9,245	8..38	157
	10	12/28/95	0.42	11,300	7.63	171
	15	12/28/95	0.42	11,305	7.62	171
	24	12/28/95	0.42	11,268	7.93	171
Clinoptilolite 5%	1	12/28/95	0.19	5,022	8.54	162
	3	12/28/95	0.17	4,669	8.49	163
	5	12/28/95	0.12	3,201	8.81	171
	10	12/28/95	0.06	1,711	8.79	176
	15	12/29/95	0.07	1,988	8.92	183
	24	12/29/95	0.06	1,535	9.34	193
Soil	1	12/29/95	0.38	10,202	8.27	147
	3	12/29/95	0.40	10,800	8.35	150
	5	12/30/95	0.43	11,547	9.03	159
	10	12/30/95	0.51	13,683	9.10	162
	15	12/30/95	0.50	13,600	8.67	157
	24	12/30/95	0.51	13,672	8.36	156
Hanford Water			0	-	7.99	150

Table B-2. Atomic Adsorbtion Spectrophotometry Data from the Kinetics Experiment

	Time hours	Na ppm			StD%	Mg ppm			StD%	Ca ppm			StD%
NC Apatite 1%	1	17	±	1.2	6.8	4.2	±	0.06	1.5	20.5	±	0.002	0.01
	3	15	±	0.1	0.6	4.3	±	0.01	0.2	22.4	±	0.2	0.8
	5	16	±	0.9	5.7	4.2	±	0.01	0.2	22.7	±	0.5	2.1
	10	16	±	0.8	4.9	4.2	±	0.01	0.2	22.8	±	1.0	4.2
	15	17	±	0.3	1.7	4.2	±	0.04	0.8	22.6	±	0.03	0.2
	24	17	±	1.3	7.7	4.2	±	0.03	0.8	23.4	±	2.4	10.1
Bone Char 5%	1	32	±	0.5	1.4	5.9	±	0.03	0.6	18.6	±	0.5	2.9
	3	30	±	0.04	0.1	6.0	±	0.004	0.1	16.1	±	0.01	0.1
	5	32	±	0.6	1.8	6.2	±	0.06	0.9	14.3	±	0.5	3.5
	10	33	±	0.7	2.0	6.8	±	0.03	0.5	11.7	±	0.03	0.3
	15	35	±	0.7	2.0	7.6	±	0.02	0.3	10.2	±	0.3	3.2
	24	35	±	0.6	1.6	7.1	±	0.02	0.3	9.2	±	0.4	4.3
Hydroxyapatite 5%	1	17	±	0.3	1.9	5.3	±	0.03	0.6	25.8	±	1.3	4.9
	3	17	±	1.2	6.8	5.5	±	0.005	0.1	25.9	±	1.5	5.7
	5	16	±	0.6	3.6	5.4	±	0.05	0.9	25.2	±	0.4	1.6
	10	18	±	0.1	0.3	5.6	±	0.01	0.2	22.1	±	0.3	1.4
	15	16	±	0.8	4.9	5.6	±	0.01	0.2	22.5	±	0.1	0.6
	24	16	±	1.3	7.8	5.7	±	0.04	0.8	23.5	±	0.1	0.6
Clinoptilolite 5%	1	35	±	0.8	2.2	2.7	±	0.08	2.9	11.1	±	0.7	5.9
	3	35	±	0.5	1.3	2.7	±	0.02	0.8	10.6	±	0.7	6.8
	5	44	±	0.3	0.6	1.9	±	0.06	3.2	5.5	±	0.5	9.3
	10	51	±	0.4	0.8	1.2	±	0.01	0.7	3.8	±	0.2	5.4
	15	53	±	0.01	0.03	1.6	±	0.02	1.3	4.1	±	0.06	1.4
	24	57	±	0.4	0.7	1.6	±	0.01	0.4	3.7	±	0.2	4.4
Soil	1	16	±	0.3	1.9	4.3	±	0.03	0.7	22.5	±	0.1	0.6
	3	16	±	0.5	2.9	4.3	±	0.03	0.6	23.5	±	0.1	0.6
	5	16	±	0.2	1.4	4.2	±	0.05	1.2	22.1	±	0.4	1.9
	10	22	±	0.6	2.6	4.2	±	0.008	0.2	11.1	±	0.3	2.6
	15	16	±	0.5	3.1	4.2	±	0.01	0.1	14.4	±	0.3	2.2
	24	17	±	1.0	6.0	4.1	±	0.03	0.8	22.7	±	0.9	3.8
Hanford Water		16	±	0.1	0.3	4.6	±	0.01	0.2	20.8	±	0.2	0.8

Table B-3. Inductively Coupled Plasma-Mass Spectrometry Data from the Kinetics Experiment (Page 1 of 7)

	Time	Chromium			Manganese			Iron		
	hours	Value	Error	StD%	Value	Error	StD%	Value	Error	StD%
NC Apatite 1%	1	0.35 ±	0.07	19.7	7.6 ±	0	0.2	242 ±	1	0.4
	3	<0.2			11.5 ±	0.2	1.7	333 ±	3.6	1.1
	5	<0.2			9.7 ±	0.1	0.6	290 ±	4.5	1.6
	10	0.38 ±	0.03	7.4	8.1 ±	0.1	1	245 ±	5.9	2.4
	15	<0.2			8.4 ±	0.1	1.1	245 ±	8.6	3.5
	24	0.22 ±	0.01	6.6	8.6 ±	0.5	5.3	238 ±	13.5	5.7
Bone Char 5%	1	1.47 ±	0.04	2.8	2.2 ±	0	0.9	214 ±	8.6	4
	3	0.83 ±	0.02	2.5	5.2 ±	0.2	3	318 ±	9	2.8
	5	0.89 ±	0.02	2.1	4.1 ±	0	1	277 ±	2.9	1
	10	0.81 ±	0.03	3.5	0.98 ±	0	3.2	139 ±	3.6	2.6
	15	1.09 ±	0.01	1.3	1.51 ±	0	2.4	148 ±	2.2	1.5
	24	1.05 ±	0.03	2.5	1.67 ±	0	1.2	135 ±	3.8	2.9
Hydroxyapatite 5%	1	3.98 ±	0.01	0.3	1 ±	0	1.8	361 ±	3	0.8
	3	3.85 ±	0.03	0.7	1.14 ±	0	1.4	391 ±	1	0.2
	5	3.76 ±	0.08	2.1	1 ±	0	1.1	358 ±	7.3	2
	10	3.68 ±	0.07	1.9	1.29 ±	0	0.6	366 ±	7.5	2.1
	15	3.45 ±	0.02	0.5	1.35 ±	0	1.1	376 ±	14	3.7
	24	3.9 ±	0.01	0.3	1.56 ±	0	1.2	419 ±	4.8	1.1
Clinoptilolite 5%	1	0.58 ±	0.02	4	24.4 ±	0.2	0.6	677 ±	9.8	1.5
	3	0.94 ±	0.07	7.3	28.5 ±	0.1	0.5	779 ±	7.6	1
	5	0.7 ±	0.01	2	25.1 ±	0.3	1	755 ±	9.1	1.2
	10	0.76 ±	0.02	3.3	22.3 ±	0.1	0.5	700 ±	5.1	0.7
	15		na			na			na	
	24		na			na			na	
Soil	1	0.24 ±	0.02	7.4	6.6 ±	0	0.7	172 ±	5.5	3.2
	3	<0.2			8.5 ±	0.1	0.7	207 ±	2.2	1.1
	5	0.31 ±	0.01	3.4	6.9 ±	0.2	3.1	180 ±	0.3	0.2
	10	0.39 ±	0.02	5.9	10.3 ±	0.1	0.6	258 ±	2.3	0.9
	15	0.26 ±	0.01	3	9.3 ±	0.2	2	201 ±	3.7	1.9
	24	0.23 ±	0.01	3.6	7.3 ±	0.1	1.1	178 ±	2.5	1.4
Hanford Water		<0.2			0.34 ±	0	5.7	170 ±	15	8.8

Table B-3. Inductively Coupled Plasma-Mass Spectrometry Data from the Kinetics Experiment (Page 2 of 7)

	Time	Copper				Zinc				Arsenic			
	Hours	Value		Error	StD%	Value		Error	StD%	Value		Error	StD%
NC Apatite 1%	1	3.85	±	0.12	3.2	1.88	±	0	1.2	0.18	±	0.03	14.4
	3	2.86	±	0.04	1.5	3.3	±	0.1	2.3	0.2	±	0.02	10.4
	5	2.24	±	0.02	1	2.54	±	0.1	3.9	0.22	±	0.04	19.9
	10	4.13	±	0.06	1.4	3.38	±	0.1	2.4	0.33	±	0.04	13.3
	15	3.15	±	0.02	0.5	3.75	±	0.1	1.3	0.36	±	0.04	11.7
	24	2.32	±	0.04	1.6	1.54	±	0.2	10.4	0.37	±	0.05	13.2
Bone Char 5%	1	5.01	±	0.07	1.3	3.44	±	0	1.2	0.14	±	0.04	29.7
	3	3.62	±	0.1	2.8	8.76	±	0.2	2.2	0.15	±	0.01	5.6
	5	4.16	±	0.1	2.3	3.75	±	0.1	3.4	0.16	±	0.02	11.1
	10	2.17	±	0.02	0.9	1.31	±	0.1	3.6	0.17	±	0.03	19.6
	15	1.57	±	0.06	4.1	6.72	±	0.1	1.6	0.12	±	0.02	15.3
	24	1.26	±	0.02	1.4	1.78	±	0	2.3	0.18	±	0.01	4.3
Hydroxyapatite 5%	1	1.02	±	0.02	1.5	2.02	±	0.2	8.4	0.05	±	0	7
	3	1.34	±	0.08	6.2	2.86	±	0	0.9	0.06	±	0.01	12.7
	5	1.08	±	0.08	7.3	2.08	±	0	0.7	0.06	±	0.01	22.8
	10	0.88	±	0.03	2.9	1.36	±	0.1	6.4	0.08	±	0.01	10.7
	15	0.88	±	0.04	4.4	1.87	±	0.1	5.2	0.1	±	0.01	8.5
	24	0.86	±	0.03	3.2	2.03	±	0.1	5.9	0.09	±	0.01	6.9
Clinoptilolite 5%	1	4.7	±	0.14	3	3.08	±	0.2	5.4	0.62	±	0.03	4.3
	3	4.81	±	0.05	1	3.84	±	0.3	7.2	0.6	±	0.02	3
	5	6.8	±	0.14	2.1	7.71	±	0.2	3.1	0.75	±	0.03	4.6
	10	5.32	±	0.04	0.7	8.86	±	0.1	1.5	1.01	±	0.05	5.2
	15			na		9.18				1.38			
	24			na		11.5				1.41			
Soil	1	2.31	±	0.06	2.6	2.59	±	0.1	3.4	0.11	±	0.02	17.9
	3	3.68	±	0.12	3.2	3.86	±	0.2	4.2	0.12	±	0.01	8
	5	2.78	±	0.14	5	2.17	±	0.2	6.8	0.16	±	0.01	5.8
	10	2.52	±	0.02	0.8	2.64	±	0	0.4	0.2	±	0.05	24.8
	15	2.31	±	0.09	4	1.97	±	0.1	4.3	0.23	±	0.03	12.6
	24	2.59	±	0.1	4	2.84	±	0.2	7.1	0.25	±	0.02	8.9
Hanford Water		1.44	±	0.07	5	4.61	±	0.2	4.1	<0.05			

Table B-3. Inductively Coupled Plasma-Mass Spectrometry Data from the Kinetics Experiment (Page 3 of 7)

	Time	Strontium				Yttrium				Silver			
	Hours	Value		Error	StD%	Value		Error	StD%	Value		Error	StD%
NC Apatite 1%	1	56.8	±	0.7	1.3	0.27	±	0.1	19.9	<0.02			
	3	56	±	0.9	1.6	1.03	±	0.1	8.2	<0.02			
	5	60.8	±	0.4	0.7	0.57	±	0	5.4	<0.02			
	10	75.5	±	1.1	1.4	2.33	±	0.1	5.7	<0.02			
	15	73	±	0.4	0.6	0.12	±	0	7.5	<0.02			
	24	76.9	±	0.8	1.1	0.06	±	0	35.4	<0.02			
Bone Char 5%	1	41.2	±	0.7	1.7	0.2	±	0	15.9	<0.02			
	3	41.9	±	0.6	1.5	0.57	±	0.1	13.2	<0.02			
	5	42.8	±	0.3	0.7	0.4	±	0.1	12.2	<0.02			
	10	41.8	±	0.5	1.1	0.07	±	0	15.3	<0.02			
	15	38.3	±	0.2	0.6	0.17	±	0	12.9	<0.02			
	24	38.5	±	0.4	1	0.15	±	0	12.4	0.024	±	0.01	40.1
Hydroxyapatite 5%	1	47.2	±	0.4	0.9	0.08	±	0	14.5	0.022	±	0	12.2
	3	54.6	±	0	0.1	<0.05				<0.02			
	5	50	±	0.5	1	<0.05				<0.02			
	10	61.6	±	0.5	0.8	<0.05				<0.02			
	15	60.7	±	0.8	1.3	<0.05				<0.02			
	24	66.3	±	0.6	0.9	<0.05				<0.02			
Clinoptilolite 5%	1	25.3	±	0.2	1	2.37	±	0.1	4.5	0.021	±	0.01	27.3
	3	24.5	±	0.4	1.4	2.6	±	0.1	3.9	<0.02			
	5	11.8	±	0.3	2.3	2	±	0.1	5.3	0.036	±	0.01	16.3
	10	7.86	±	0.12	1.5	1.82	±	0.1	5.9	<0.02			
	15	10.3				na				0.028			
	24	8.71				na				0.029			
Soil	1	52.5	±	0.2	0.5	0.09	±	0	14.6	<0.02			
	3	60.3	±	0.6	1.1	0.28	±	0	12	<0.02			
	5	59.3	±	1.2	2.1	0.09	±	0	20.8	<0.02			
	10	66.4	±	0.8	1.2	0.44	±	0.1	13	0.114	±	0.03	23.8
	15	71.1	±	0.5	0.7	0.15	±	0	20	0.02	±	0.01	40.6
	24	68.7	±	1.6	2.3	0.06	±	0	24.3	0.032	±	0.01	20.8
Hanford Water		5.76	±	0.16	2.9	0.06	±	0	13.5	0.023	±	0.01	20.9

Table B-3. Inductively Coupled Plasma-Mass Spectrometry Data from the Kinetics Experiment (Page 4 of 7)

	Time	Cesium				Barium				Lanthanum			
	Hours	Value		Error	StD%	Value		Error	StD%	Value		Error	StD%
NC Apatite 1%	1	0.27	±	0.01	2.6	10.5	±	0.1	1.1	0.27	±	0.01	2.6
	3	0.3	±	0.01	2.5	11.5	±	0.1	0.5	0.95	±	0.05	5.1
	5	0.25	±	0	1.7	11.4	±	0.2	2.1	0.5	±	0.15	29.1
	10	0.26	±	0.01	2.6	11.6	±	0.2	1.4	1.33	±	0.14	10.7
	15	0.26	±	0	1.4	11.8	±	0.2	1.3	<0.1			
	24	0.25	±	0.02	7.5	12.8	±	0.2	1.9	<0.1			
Bone Char 5%	1	0.19	±	0	1.5	11.7	±	0.1	1	0.19	±	0.01	7.1
	3	0.2	±	0.01	5.1	12.4	±	0.1	1	0.38	±	0.02	4.7
	5	0.21	±	0	0.8	12.4	±	0.1	0.5	0.35	±	0.02	5.3
	10	0.25	±	0.01	3.1	10.7	±	0.1	0.9	<0.1			
	15	0.19	±	0	1.4	11.5	±	0.1	0.8	0.14	±	0.02	15.7
	24	0.19	±	0	2	10.9	±	0.1	0.8	0.14	±	0.05	34.5
Hydroxyapatite 5%	1	0.18	±	0.01	3	9.9	±	0.1	1.2	0.25	±	0.02	6.6
	3	0.2	±	0	1.1	11.3	±	0.1	0.9	<0.1			
	5	0.22	±	0	1.7	10.7	±	0.1	0.5	<0.1			
	10	0.21	±	0	0.7	12.1	±	0.1	0.8	<0.1			
	15	0.2	±	0	1	12.3	±	0	0.3	<0.1			
	24	0.22	±	0	0.8	13.7	±	0.1	0.9	<0.1			
Clinoptilolite 5%	1	0.24	±	0	0.9	10.3	±	0.1	0.9	2.94	±	0.19	6.3
	3	0.24	±	0	0.6	11	±	0.2	1.4	3.27	±	0.06	1.8
	5	0.23	±	0	1	8.15	±	0.2	2.2	2.5	±	0.1	4.1
	10	0.26	±	0	0.8	6.86	±	0.2	2.5	2.25	±	0.09	4
	15	0.25						na				na	
	24	0.24						na				na	
Soil	1	0.23	±	0	1.6	9.9	±	0.1	0.9	<0.1			
	3	0.25	±	0.01	2.3	10.8	±	0.2	1.9	0.17	±	0.01	4.4
	5	0.23	±	0	0.6	10.2	±	0.1	0.6	<0.1			
	10	0.24	±	0	0.9	12.5	±	0.2	1.9	0.34	±	0.02	7.3
	15	0.23	±	0.01	2.3	11.3	±	0.2	1.5	<0.1			
	24	0.24	±	0.01	1.9	11.2	±	0	0.2	<0.1			
Hanford Water		0.25	±	0	0.7	0.25	±	0	8	<0.1			

Table B-3. Inductively Coupled Plasma-Mass Spectrometry Data from the Kinetics Experiment (Page 5 of 7)

	Time	Cerium				Praeseodymium				Samarium			
	Hours	Value		Error	StD%	Value		Error	StD%	Value		Error	StD%
NC Apatite 1%	1	0.27	±	0.02	7.6	<0.05				<0.05			
	3	1.32	±	0.03	2.4	0.16	±	0	14.2	0.19	±	0.07	35
	5	0.77	±	0.04	4.8	0.09	±	0	10.3	0.1	±	0.05	49
	10	1.24	±	0.04	3.1	0.19	±	0	4.8	0.14	±	0.04	25
	15	0.18	±	0.03	19.1	<0.05				<0.05			
	24	<0.1				<0.05				<0.05			
Bone Char 5%	1	0.33	±	0.05	14.9	<0.05				0.07	±	0.11	150
	3	0.9	±	0.08	8.4	0.12	±	0	6	0.1	±	0.09	92
	5	0.7	±	0.04	5.6	0.09	±	0	37.2	0.11	±	0.03	24
	10	<0.1				<0.05				<0.05			
	15	0.28	±	0.01	3.5	<0.05				0.05	±	0.06	111
	24	0.29	±	0.05	15.6	<0.05				<0.05			
Hydroxyapatite 5%	1	0.17	±	0.02	9.2	<0.05				<0.05			
	3	<0.1				<0.05				<0.05			
	5	<0.1				<0.05				<0.05			
	10	<0.1				<0.05				<0.05			
	15	<0.1				<0.05				<0.05			
	24	<0.1				<0.05				0.05	±	0.03	50
Clinoptilolite 5%	1	6.23	±	0.25	4	0.62	±	0.1	12	0.47	±	0.15	31
	3	7.59	±	0.18	2.3	0.79	±	0	4.4	0.67	±	0.1	16
	5	7.05	±	0.16	2.3	0.56	±	0	1.4	0.54	±	0.08	16
	10	6.53	±	0.11	1.7	0.58	±	0	5.1	0.38	±	0.08	22
	15			na				na				na	
	24			na				na				na	
Soil	1	<0.1				<0.05				<0.05			
	3	0.46	±	0.01	1.9	0.07	±	0	14.5	0.1	±	0.03	31
	5	0.17	±	0.04	21.2	<0.05				0.09	±	0.07	78
	10	1.06	±	0.12	11.5	0.13	±	0	22.3	0.07	±	0.01	19
	15	0.2	±	0.03	15.8	<0.05				<0.05			
	24	<0.1				<0.05				0.06	±	0.07	116
Hanford Water		<0.1				<0.05				0.08	±	0.05	62

Table B-3. Inductively Coupled Plasma-Mass Spectrometry Data from the Kinetics Experiment (Page 6 of 7)

	Time	Europium				Gadolinium				Dysprosium			
	Hours	Value		Error	StD%	Value		Error	StD%	Value		Error	StD%
NC Apatite 1%	1	<0.05				0.03	±	0	77	<0.05			
	3	0.09	±	0.01	11	0.21	±	0.1	49	0.15	±	0.04	30
	5	<0.05				0.12	±	0	34	0.11	±	0.05	49
	10	0.08	±	0.01	11	0.28	±	0.1	25	0.32	±	0.05	16
	15	<0.05				0.03	±	0	120	<0.05			
	24	<0.05				0.05	±	0	3	<0.05			
Bone Char 5%	1	<0.05				0.07	±	0.1	78	0.1	±	0.05	52
	3	<0.05				0.19	±	0.1	49	0.08	±	0.08	99
	5	<0.05				0.15	±	0.1	60	0.1	±	0.03	35
	10	<0.05				0.08	±	0	49	<0.05			
	15	<0.05				0.06	±	0	70	0.06	±	0.02	37
	24	<0.05				0.08	±	0.1	77	<0.05			
Hydroxyapatite 5%	1	<0.05				0.04	±	0	36	<0.05			
	3	<0.05				<0.02				<0.05			
	5	<0.05				<0.02				<0.05			
	10	<0.05				0.02	±	0	85	<0.05			
	15	<0.05				0.03	±	0	149	<0.05			
	24	<0.05				0.05	±	0	9	<0.05			
Clinoptilolite 5%	1	0.11	±	0.03	29	0.38	±	0.1	20	0.52	±	0.12	23
	3	0.14	±	0.01	10	0.55	±	0.1	21	0.57	±	0.08	14
	5	0.12	±	0.02	16	0.51	±	0.1	12	0.53	±	0.01	2
	10	0.11	±	0.05	48	0.46	±	0	6	0.49	±	0.14	29
	15			na				na				na	
	24			na				na				na	
Soil	1	<0.05				0.07	±	0	59	0.09	±	0.04	44
	3	0.06	±	0.02	41	0.08	±	0	29	0.09	±	0.06	65
	5	0.09	±	0.06	66	0.05	±	0.1	99	0.06	±	0.03	48
	10	0.06	±	0.04	76	0.12	±	0	7	0.12	±	0.08	70
	15	<0.05				0.08	±	0	18	0.07	±	0.03	43
	24	<0.05				0.05	±	0	18	0.05	±	0.04	83
Hanford Water		<0.05				0.42	±	0	9	0.03	±	0.02	54

Table B-3. Inductively Coupled Plasma-Mass Spectrometry Data from the Kinetics Experiment (Page 7 of 7)

	Time	Holmium				Erbium				Lead			
	Hours	Value		Error	StD%	Value		Error	StD%	Value		Error	StD%
NC Apatite 1%	1	<0.02				<0.05				0.19	±	0.02	9.7
	3	0.05	±	0.01	18	0.1	±	0	13	0.31	±	0.01	2.9
	5	0.03	±	0	13	<0.05				0.19	±	0.01	5.7
	10	0.04	±	0.01	31	0.1	±	0	31	0.1	±	0	0.6
	15	<0.02				<0.05				0.17	±	0.03	14.5
	24	<0.02				<0.05				<0.1			
Bone Char 5%	1	<0.02				<0.05				0.16	±	0.01	9
	3	<0.02				0.15	±	0.1	34	0.3	±	0.03	8.8
	5	0.03	±	0.02	84	0.11	±	0	36	0.2	±	0.02	7.9
	10	<0.02				0.07	±	0	30	<0.1			
	15	0.02	±	0.01	24	0.06	±	0	63	0.12	±	0.01	11.4
	24	<0.02				0.07	±	0	47	<0.1			
Hydroxyapatite 5%	1	<0.02				<0.05				0.17	±	0.02	9.6
	3	<0.02				<0.05				0.17	±	0.01	3.9
	5	<0.02				<0.05				0.13	±	0.01	10.4
	10	<0.02				<0.05				<0.1			
	15	<0.02				<0.05				0.13	±	0.01	8.9
	24	<0.02				<0.05				<0.1			
Clinoptilolite 5%	1	0.08	±	0.02	19	0.36	±	0.1	26	0.58	±	0.02	3.3
	3	0.11	±	0.02	14	0.47	±	0.1	23	0.64	±	0.03	5
	5	0.08	±	0.02	24	0.33	±	0.1	16	1.45	±	0.02	1.1
	10	0.08	±	0.02	23	0.36	±	0	3	0.73	±	0.01	1.3
	15			na				na				na	
	24			na				na				na	
Soil	1	<0.02				0.05	±	0	86	0.14	±	0.02	11.4
	3	0.02	±	0.02	82	0.03	±	0	71	0.38	±	0.01	3.1
	5	0.03	±	0.01	26	0.04	±	0	88	0.19	±	0.02	8.6
	10	0.04	±	0.02	48	0.06	±	0	53	0.25	±	0.04	14.1
	15	<0.02				0.06	±	0	36	0.14	±	0.01	7.1
	24	<0.02				0.03	±	0	41	0.11	±	0	3.5
Hanford Water		<0.02				<0.02				0.31	±	0.03	9.3

APPENDIX C.

Experiment C: Loading Capacity of Sorbents

Table C-1. Results of the Loading Capacity Experiment

System	Concentration of Sr in solution after 48 hours agitation.				Calculated concentration of Sr in solid phase after 48 hours agitation.				
	C(sol'n) ppm		StD	StD%	C(solid) ppm		StD	StD%	C(solid)/C(sol'n) Kd
3 g NC Apatite and 0.01 g Sr(NO3)2/30 mL water	51.7	±	0.72	1.4	80.9	±	3.80	4.7	1.57
3 g Bone Char and 0.01 g Sr(NO3)2/30 mL water	0.36	±	0.05	13.5	132.3	±	18.8	14.2	371
3 g Hydroxyapatite and 0.01 g Sr(NO3)2/30 mL water	16.3	±	0.49	3.0	116.3	±	6.29	5.4	7.11
3 g Clinoptilolite and 0.01 g Sr(NO3)2/30 mL water	0.23	±	0.00	0.7	132.4	±	6.02	4.5	585
Original solution 0.01 g Sr(NO3)2/30 mL water	132.6	±	6.0	4.5	0.0	±	0.0	0.0	0.00
3 g NC Apatite and 0.1 g Sr(NO3)2/30 mL water	996	±	42	4.2	265	±	19	7.3	0.27
3 g Bone Char and 0.1 g Sr(NO3)2/30 mL water	261	±	16	6.2	1,000	±	86	8.6	3.83
3 g Hydroxyapatite and 0.1 g Sr(NO3)2/30 mL water	589	±	17	2.9	672	±	44	6.6	1.14
3 g Clinoptilolite and 0.1 g Sr(NO3)2/30 mL water	143	±	4.9	3.4	1,118	±	76.2	6.8	7.80
Original solution 0.1 g Sr(NO3)2/30 mL water	1,261	±	75	5.9	0	±	0	0.0	0.00
3 g NC Apatite and 1 g Sr(NO3)2/30 mL water	12,684	±	1,064	8.4	934	±	158	17.0	0.07
3 g Bone Char and 1 g Sr(NO3)2/30 mL water	10,400	±	1,122	10.8	3,218	±	588	18.3	0.31
3 g Hydroxyapatite and 1 g Sr(NO3)2/30 mL water	11,321	±	1,369	12.1	2,296	±	438	19.1	0.20
3 g Clinoptilolite and 1 g Sr(NO3)2/30 mL water	9,632	±	1,255	13.0	3,985	±	784	19.7	0.41
Original solution 1 g Sr(NO3)2/30 mL water	13,618	±	2,008	14.7	0	±	0	0.0	0.00

APPENDIX D.

Experiment D: pH Stability Test

Table D-1. Ion Chromotography Data from the pH Stability Test, Saturation Step

	Treatment Number	Fluoride ppm	Chloride ppm	Nitrate ppm	Phosphate ppm	Sulfate ppm
Hanford Water	1	<0.1	<0.1	12.8	<0.5	19.1
	2	<0.1	<0.1	13.1	<0.5	18.7
	3	<0.1	<0.1	12.8	<0.5	18.6
NC Apatite 1%	1	0.98	25.3*	23.5	2.12	124.2
	2	0.95	2.26	35.7	0.87	143.0
	3	0.61	1.86	20.0	0.57	147.6
Bone Char 5%	1	not analyzed	52.1	52.0	0.61	93.5
	2	not analyzed	50.6	26.0	0.48	89.5
	3	not analyzed	39.5	12.6	0.61	85.0
Hydroxyapatite 5%	1	0.20	28.3	7.1	<0.5	6.62
	2	0.15	12.7	16.8	0.75	8.50
	3	0.15	8.67	12.1	0.92	7.53
Clinoptilolite 5%	1	1.05	40.4	23.3	2.19	70.8
	2	1.08	62.5	42.0	4.92	136.6
	3	2.17	66.5	57.3	3.58	137.3
Maximal error of analysis in percent		1.74	2.48	0.38	0.29	0.67

* An error was made during the preparation of the samples in Treatment 1 when 0.01M KCl solution was mistakenly added instead of Hanford simulated groundwater. After discovery of this mistake, the samples were dried in an oven and then saturated with Hanford groundwater. This error could have increased concentration of chloride in the solutions.

Table D-2. Strontium-90 Data by Liquid Scintillation for the pH Stability Test, Saturation Step

	pH of added water	Treatment 1 Date of counting	Treatment 1 Sr-90 Bq/mL	Treatment 1 pCi/L	Treatment 2 Date of counting	Treatment 2 Sr-90 Bq/mL	Treatment 2 pCi/L	Treatment 3 Date of counting	Treatment 3 Sr-90 Bq/mL	Treatment 3 pCi/L
NC Apatite 1%	9	12/30/95	0.888	23,998	1/5/96	0.706	19,070	1/22/96	0.738	19,957
	8	12/30/95	0.843	22,794	1/5/96	0.845	22,851	1/22/96	0.859	23,227
	7	12/30/95	0.707	19,118	1/5/96	0.810	21,891	1/22/96	0.772	20,851
	6	12/30/95	0.805	21,743	1/5/96	0.972	26,260	1/22/96	0.786	21,241
	5	12/30/95	0.867	23,440	1/5/96	0.955	25,815	1/22/96	0.867	23,426
Bone Char 5%	9	12/30/95	0.093	2,519	1/5/96	0.065	1,766	1/22/96	0.056	1,518
	8	12/30/95	0.107	2,887	1/5/96	0.088	2,383	1/22/96	0.065	1,766
	7	12/30/95	0.065	1,765	1/6/96	0.066	1,792	1/22/96	0.050	1,363
	6	12/30/95	0.103	2,794	1/6/96	0.086	2,320	1/22/96	0.066	1,793
	5	12/31/95	0.092	2,484	1/6/96	0.078	2,121	1/23/96	0.041	1,104
Hydroxyapatite 5%	9	12/31/95	0.485	13,118	1/6/96	0.505	13,635	1/23/96	0.452	12,218
	8	12/31/95	0.573	15,498	1/6/96	0.584	15,796	1/23/96	0.443	11,982
	7	12/31/95	0.489	13,229	1/6/96	0.576	15,568	1/23/96	0.490	13,245
	6	12/31/95	0.554	14,978	1/6/96	0.634	17,145	1/23/96	0.518	14,000
	5	12/31/95	0.598	16,149	1/6/96	0.572	15,467	1/23/96	0.520	14,050
Clinoptilolite 5%	9	12/31/95	0.061	1,652	1/6/96	0.024	636	1/23/96	0.019	516
	8	12/31/95	0.043	1,154	1/6/96	0.054	1,471	1/23/96	0.019	502
	7	12/31/95	0.029	793	1/6/96	0.030	818	1/23/96	0.015	396
	6	12/31/95	0.031	839	1/6/96	0.043	1,175	1/23/96	0.016	439
	5	12/31/95	0.024	653	1/7/96	0.041	1,097	1/23/96	0.036	982
Soil	9	1/1/96	0.847	22,900	1/7/96	0.656	17,716	1/24/96	0.644	17,394
	8	1/1/96	0.783	21,158	1/7/96	0.628	16,968	1/24/96	0.718	19,414
	7	1/1/96	0.730	19,724	1/7/96	0.633	17,102	1/24/96	0.723	19,552
	6	1/1/96	0.573	15,489	1/7/96	0.718	19,409	1/24/96	0.751	20,286
	5	1/1/96	0.732	19,790	1/7/96	0.696	18,798	1/24/96	0.846	22,867
NC Apatite 1%	48 hr	1/1/96	0.529	14,304	1/8/96	0.406	10,976	1/24/96	0.406	10,968
Bone Char 5%	48 hr	1/1/96	0.222	5,997	1/8/96	0.109	2,959	1/24/96	0.235	6,345
Hydroxyapatite	48 hr	1/1/96	0.345	9,322	1/8/96	0.284	7,677	1/24/96	0.337	9,106
Clinoptilolite 5%	48 hr	1/2/96	0.048	1,307	1/8/96	0.031	847	1/25/96	0.039	1,054
Soil	48 hr	1/2/96	0.512	13,833	1/8/96	0.396	10,704	1/25/96	0.480	12,982
Hanford Water	9		0.000	-		0.000	-		0.000	-
	8		0.000	-		0.000	-		0.000	-
	7		0.000	-		0.000	-		0.000	-
	6		0.000	-		0.000	-		0.000	-
	5		0.000	-		0.000	-		0.000	-
Hanford Water	48 hr, Satur.		0.000	-		0.000	-		0.000	-
NC Apatite 1%	Satur.	1/2/96	1.535	41,498	1/8/96	1.639	44,306	1/25/96	1.387	37,486
Bone Char 5%	Satur.	1/2/96	0.198	5,341	1/8/96	0.147	3,984	1/25/96	0.145	3,917
Hydroxyapatite 5%	Satur.	1/2/96	0.794	21,463	1/8/96	0.656	17,717	1/25/96	0.330	8,910
Clinoptilolite 5%	Satur.	1/2/96	0.072	1,957	1/8/96	0.030	803	1/25/96	0.082	2,218

Table D-3. Conductivity and pH Data by Liquid Scintillation for the pH Stability Test, Saturation Step

		Treatment 1		Treatment 2		Treatment 3	
	pH	pH	Cond.	pH	Cond.	pH	Cond.
	of added water		microSi/cm		microSi/cm		microSi/cm
NC Apatite 1%	9	8.62	203	7.87	192	8.02	169
	8	8.48	195	8.06	198	8.41	193
	7	7.81	187	7.92	198	7.98	210
	6	8.91	193	7.90	219	8.46	197
	5	7.86	192	7.05	204	8.23	206
Bone Char 5%	9	9.18	504	9.02	508	9.06	509
	8	9.11	459	9.12	523	9.25	501
	7	9.06	409	9.18	486	9.05	506
	6	9.09	466	8.95	488	9.37	585
	5	9.09	475	8.66	543	9.31	513
Hydroxyapatite 5%	9	8.07	192	8.47	190	8.51	187
	8	8.05	192	8.27	202	8.34	190
	7	7.74	189	8.32	227	8.74	217
	6	7.52	193	8.25	211	8.50	208
	5	7.75	215	8.37	235	8.48	222
Clinoptilolite 5%	9	8.97	423	9.06	356	9.60	396
	8	9.47	320	9.62	364	9.91	404
	7	9.81	358	9.65	400	9.49	406
	6	9.67	406	9.53	394	9.95	418
	5	9.91	410	8.52	371	10.17	417
Soil	9	8.13	196	9.28	222	8.35	146
	8	8.99	200	8.78	197	8.27	169
	7	9.53	194	8.43	198	8.39	197
	6	9.76	206	8.91	241	8.44	197
	5	9.41	208	9.14	233	8.37	198
NC Apatite 1%	48 hr	8.10	169	8.39	132	8.22	190
Bone Char 5%	48 hr	9.11	191	9.08	191	8.45	214
HAP 5%	48 hr	8.30	184	8.63	168	8.44	149
Clinoptilite 5%	48 hr	9.39	208	9.56	194	9.28	192
Soil	48 hr	8.78	165	8.81	141	8.50	164
Hanford Water	9	8.90	163	9.16	116	8.99	106
	8	7.09	119	7.80	115	8.03	149
	7	8.00	145	6.99	108	7.02	159
	6	6.36	118	6.10	141	6.06	147
	5	5.04	118	5.14	128	5.01	154
Hanford Water	48 hr, Satur.	8.15	152	8.21	118	8.20	153
NC Apatite 1%	Satur.	8.20	388	7.71	348	7.00	306
Bone Char 5%	Satur.	8.44	1076	8.74	936	10.13	940
HAP 5%	Satur.	8.35	308	8.00	262	8.82	223
Clinoptilolite 5%	Satur.	8.61	364	8.76	668	7.24	691

Table D-4a. Atomic Absorption Spectrophotometry Data for the pH Stability Test: Sodium

	pH of added water	Treatment 1 ppm	StD%	Treatment 2 ppm	StD%	Treatment 3 ppm	StD%
NC Apatite 1%	9	19 ± 0.2	0.8	20 ± 0.8	4.1	18 ± 0.1	0.5
	8	21 ± 0.1	0.6	20 ± 0.6	3.0	18 ± 0.8	4.3
	7	22 ± 1.6	7.1	20 ± 0.9	4.5	18 ± 0.1	0.3
	6	20 ± 0.5	2.4	19 ± 0.2	0.9	17 ± 0.7	4.1
	5	22 ± 1.2	5.2	20 ± 0.1	0.7	19 ± 0.3	1.8
Bone Char 5%	9	137 ± 0.4	0.3	138 ± 1.7	1.2	157 ± 2.5	1.6
	8	118 ± 0.2	0.2	147 ± 1.3	0.9	119 ± 1.9	1.6
	7	138 ± 0.9	0.7	135 ± 0.3	0.2	268 ± 47	17.6
	6	122 ± 1.3	1.1	141 ± 0.3	0.2	255 ± 40	15.5
	5	127 ± 1.3	1.1	144 ± 0.2	0.2	192 ± 22	11.5
Hydroxyapatite 5%	9	18 ± 0.4	2.0	20 ± 1.4	7.0	19 ± 0.5	2.4
	8	19 ± 0.7	3.8	21 ± 0.4	2.0	18 ± 0.1	0.6
	7	20 ± 0.02	0.1	20 ± 0.46	2.3	19 ± 0.85	4.5
	6	21 ± 0.4	1.9	19 ± 1.0	5.1	18 ± 0.3	1.8
	5	20 ± 0.8	3.9	19 ± 0.2	1.1	18 ± 0.0	0.3
Clinoptilolite 5%	9	131 ± 0.9	0.7	112 ± 0.7	0.6	113 ± 0.9	0.8
	8	101 ± 1.2	1.2	101 ± 0.4	0.4	109 ± 0.2	0.1
	7	110 ± 0.2	0.2	na		114 ± 0.2	0.1
	6	113 ± 0.8	0.7	105 ± 2.8	2.7	112 ± 1.3	1.2
	5	111 ± 1.0	0.9	110 ± 1.8	1.7	108 ± 0.2	0.2
Soil	9	21 ± 1.1	5.2	21 ± 2.3	10.9	18 ± 0.7	4.0
	8	22 ± 1.4	6.5	21 ± 0.3	1.2	18 ± 0.005	0.03
	7	21 ± 0.05	0.2	19 ± 1.10	5.8	17 ± 0.007	0.04
	6	19 ± 0.4	2.3	21 ± 0.9	4.1	16 ± 0.7	4.5
	5	20 ± 0.3	1.4	20 ± 1.7	8.4	17 ± 0.4	2.2
NC Apatite 1%	48 hr	16 ± 0.6	3.9	17 ± 2.6	14.9	13 ± 0.05	0.4
Bone Char 5%	48 hr	31 ± 0.2	0.5	34 ± 3.0	8.9	35 ± 0.5	1.5
Hydroxyapatite 5%	48 hr	17 ± 0.1	0.8	16 ± 1.7	10.5	14 ± 0.3	2.3
Clinoptilolite 5%	48 hr	55 ± 0.0	0.1	54 ± 2.2	4.0	55 ± 0.3	0.6
Soil	48 hr	17 ± 0.9	5.4	17 ± 2.5	14.8	14 ± 0.8	5.4
Hanford Water	9	15 ± 0.5	3.6	16 ± 2.6	16.1	14 ± 0.04	0.3
	8	16 ± 0.9	5.9	17 ± 2.7	16.4	16 ± 0.3	1.9
	7	16 ± 0.1	0.7	15 ± 0.8	5.4	14 ± 0.4	2.7
	6	17 ± 0.8	4.8	16 ± 0.2	1.6	15 ± 0.4	2.6
	5	16 ± 0.3	1.8	15 ± 0.1	0.8	16 ± 0.3	2.1
Hanford Water	48 hr, Satur.	15 ± 1.5	10.3	13 ± 0.1	1.0	14 ± 0.4	2.6
NC Apatite 1%	Satur.	30 ± 0.5	1.6	25 ± 0.1	0.4	24 ± 0.8	3.5
Bone Char 5%	Satur.	320 ± 51	15.9	336 ± 36	10.7	241 ± 8	3.4
Hydroxyapatite 5%	Satur.	25 ± 0.4	1.4	33 ± 0.4	1.2	22 ± 0.8	3.6
Clinoptilolite 5%	Satur.	107 ± 2	1.9	283 ± 66	23.3	189 ± 2	1.2

Table D-4b. Atomic Absorption Spectrophometry Data for the pH Stability Test: Magnesium

	pH of added water	Treatment 1 ppm			StD%	Treatment 2 ppm			StD%	Treatment 3 ppm			StD%
NC Apatite 1%	9	2.48	±	0.004	0.2	2.24	±	0.014	0.6	2.89	±	0.02	0.8
	8	2.05	±	0.004	0.2	2.77	±	0.020	0.7	3.46	±	0.02	0.7
	7	2.34	±	0.029	1.2	2.56	±	0.011	0.4	3.12	±	0.02	0.7
	6	1.97	±	0.001	0.05	3.07	±	0.022	0.7	3.02	±	0.005	0.2
	5	2.36	±	0.002	0.1	2.95	±	0.020	0.7	3.69	±	0.02	0.7
Bone Char 5%	9	1.27	±	0.001	0.1	1.03	±	0.023	2.3	1.21	±	0.01	0.8
	8	1.04	±	0.002	0.2	1.52	±	0.029	1.9	1.24	±	0.01	0.7
	7	1.27	±	0.0005	0.04	1.38	±	0.000	0.0	1.43	±	0.01	0.6
	6	1.38	±	0.002	0.2	1.52	±	0.028	1.8	1.43	±	0.01	0.6
	5	1.61	±	0.005	0.3	1.38	±	0.001	0.1	1.24	±	0.01	0.6
Hydroxyapatite 5%	9	5.33	±	0.008	0.1	5.27	±	0.064	1.2	4.92	±	0.05	1.0
	8	4.59	±	0.005	0.1	6.02	±	0.016	0.3	5.13	±	0.02	0.4
	7	5.01	±	0.012	0.2	5.90	±	0.013	0.2	6.04	±	0.08	1.3
	6	5.55	±	0.021	0.4	6.03	±	0.039	0.6	5.90	±	0.06	1.0
	5	5.89	±	0.028	0.5	5.99	±	0.037	0.6	6.26	±	0.03	0.5
Clinoptilolite 5%	9	0.27	±	0.024	8.9	0.12	±	0.014	11.0	0.20	±	0.01	6.6
	8	0.13	±	0.004	3.3	0.16	±	0.013	8.3	0.16	±	0.01	8.3
	7	0.13	±	0.004	3.2				na	0.19	±	0.01	7.0
	6	0.13	±	0.004	3.0	0.16	±	0.022	13.9	0.12	±	0.01	11.6
	5	0.13	±	0.004	2.9	0.15	±	0.021	13.5	0.14	±	0.01	9.2
Soil	9	3.51	±	0.015	0.4	2.13	±	0.008	0.4	2.66	±	0.01	0.5
	8	2.84	±	0.013	0.5	2.32	±	0.010	0.4	3.09	±	0.01	0.3
	7	3.16	±	0.015	0.5	2.11	±	0.039	1.9	3.19	±	0.02	0.6
	6	2.91	±	0.041	1.4	2.71	±	0.042	1.5	3.32	±	0.01	0.2
	5	3.32	±	0.015	0.5	2.58	±	0.017	0.7	3.62	±	0.003	0.1
NC Apatite 1%	48 hr	4.51	±	0.020	0.4	3.71	±	0.022	0.6	3.83	±	0.03	0.7
Bone Char 5%	48 hr	6.76	±	0.002	0.0	5.47	±	0.057	1.1	6.52	±	0.02	0.3
Hydroxyapatite 5%	48 hr	5.60	±	0.002	0.0	4.39	±	0.031	0.7	4.43	±	0.03	0.8
Clinoptilolite 5%	48 hr	1.06	±	0.022	2.0	0.76	±	0.019	2.5	0.73	±	0.01	1.6
Soil	48 hr	4.45	±	0.049	1.1	3.44	±	0.036	1.1	3.80	±	0.00	0.0
Hanford Water	9	4.08	±	0.020	0.5	4.52	±	0.073	1.6	4.54	±	0.03	0.6
	8	4.35	±	0.022	0.5	4.33	±	0.075	1.7	4.44	±	0.05	1.1
	7	4.35	±	0.023	0.5	4.46	±	0.007	0.2	4.48	±	0.01	0.2
	6	4.37	±	0.004	0.1	4.44	±	0.020	0.5	4.44	±	0.04	0.9
	5	4.33	±	0.051	1.2	4.41	±	0.032	0.7	4.48	±	0.03	0.8
Hanford Water	48 hr, Satur.	4.62	±	0.026	0.6	4.61	±	0.006	0.1	4.59	±	0.03	0.6
NC Apatite 1%	Satur.	5.39	±	0.062	1.1	6.35	±	0.015	0.2	6.13	±	0.02	0.3
Bone Char 5%	Satur.	5.23	±	0.004	0.1	4.73	±	0.005	0.1	3.72	±	0.03	0.8
Hydroxyapatite 5%	Satur.	9.05	±	0.109	1.2	7.92	±	0.006	0.1	5.62	±	0.02	0.3
Clinoptilolite 5%	Satur.	1.25	±	0.001	0.1	0.74	±	0.012	1.7	0.79	±	0.01	1.0

Table D-4c. Atomic Absorption Spectrophotometry Data for the pH Stability Test: Calcium

	pH of added water	Treatment 1 ppm			StD%	Treatment 2 ppm			StD%	Treatment 3 ppm			StD%
NC Apatite 1%	9	32.2	±	0.5	1.6	26.7	±	0.5	1.8	28.9	±	0.8	2.8
	8	26.0	±	0.4	1.7	30.1	±	0.7	2.2	31.2	±	0.6	2.0
	7	28.5	±	0.5	1.7	29.9	±	0.4	1.5	29.5	±	0.2	0.8
	6	27.2	±	0.5	1.7	33.9	±	0.4	1.3	28.9	±	0.04	0.1
	5	30.4	±	0.5	1.6	11.1	±	0.4	3.2	50.8	±	0.4	0.7
Bone Char 5%	9	1.91	±	0.13	7.0	1.78	±	0.01	0.6	1.98	±	0.04	2.2
	8	1.80	±	0.02	1.2	2.28	±	0.01	0.6	1.86	±	0.01	0.8
	7	2.03	±	0.01	0.5	2.20	±	0.01	0.6	2.51	±	0.02	0.7
	6	2.26	±	0.002	0.1	1.87	±	0.01	0.8	2.19	±	0.02	0.7
	5	2.26	±	0.01	0.5	5.61	±	0.05	0.8	2.35	±	0.02	0.7
Hydroxyapatite 5%	9	31.1	±	0.01	0.04	27.8	±	0.2	0.8	24.6	±	0.1	0.5
	8	26.8	±	0.3	1.1	30.5	±	0.1	0.2	24.0	±	0.7	2.8
	7	28.6	±	0.01	0.1	29.8	±	0.4	1.3	28.7	±	0.4	1.2
	6	30.4	±	0.2	0.5	30.9	±	0.2	0.5	28.7	±	0.03	0.1
	5	33.1	±	0.03	0.1	10.2	±	0.1	0.8	30.4	±	0.4	1.2
Clinoptilolite 5%	9	2.11	±	0.02	1.0	1.42	±	0.03	2.1	1.53	±	0.08	5.3
	8	1.22	±	0.03	2.4	1.38	±	0.03	2.3	1.36	±	0.08	5.9
	7	1.22	±	0.03	2.6				na	1.66	±	0.02	1.2
	6	1.38	±	0.04	2.6	1.37	±	0.01	0.9	1.15	±	0.02	1.5
	5	1.18	±	0.09	7.8	2.12	±	0.02	0.8	1.15	±	0.02	1.4
Soil	9	30.2	±	0.4	1.5	27.9	±	0.2	0.5	21.5	±	0.7	3.3
	8	23.4	±	0.1	0.5	31.1	±	0.1	0.2	25.0	±	0.0	0.1
	7	25.7	±	0.7	2.6	28.8	±	0.1	0.2	26.9	±	0.2	0.8
	6	22.4	±	0.6	2.7	34.2	±	0.3	0.8	27.0	±	0.4	1.5
	5	26.3	±	0.2	0.6	32.7	±	0.6	1.9	29.7	±	0.3	0.9
NC Apatite 1%	48 hr	25.8	±	0.0	0.1	16.6	±	0.2	1.2	27.8	±	0.1	0.3
Bone Char 5%	48 hr	9.1	±	0.2	2.5	6.1	±	0.1	2.3	14.0	±	0.1	1.0
Hydroxyapatite 5%	48 hr	25.6	±	0.4	1.5	12.0	±	8.6	71.6	21.3	±	0.3	1.3
Clinoptilolite 5%	48 hr	2.82	±	0.03	1.1	1.81	±	0.01	0.5	2.26	±	0.01	0.3
Soil	48 hr	25.9	±	0.4	1.5	17.3	±	0.1	0.4	23.5	±	0.8	3.2
Hanford Water	9	26.4	±	0.1	0.2	11.6	±	0.2	1.8	21.1	±	4.5	21.3
	8	10.9	±	0.1	0.7	14.0	±	0.1	0.4	20.4	±	0.5	2.4
	7	19.3	±	0.1	0.3	10.9	±	0.1	1.2	14.7	±	0.4	2.7
	6	11.4	±	0.1	0.8	16.1	±	0.05	0.3	14.4	±	0.2	1.4
	5	11.7	±	0.1	0.8	12.4	±	0.1	1.2	17.1	±	0.4	2.3
Hanford Water	48hr, Satur.	88.2	±	3.9	4.5	27.1	±	0.2	0.7	30.3	±	0.7	2.2
NC Apatite 1%	Satur.	64.6	±	0.9	1.4	63.6	±	0.7	1.1	53.9	±	0.8	1.5
Bone Char 5%	Satur.	8.5	±	0.1	0.7	6.0	±	0.04	0.7	3.99	±	0.23	5.7
Hydroxyapatite 5%	Satur.	14.8	±	0.2	1.1	36.2	±	0.8	2.1	24.9	±	0.2	0.8
Clinoptilite 5%	Satur.	17.4	±	0.2	1.1	6.0	±	0.1	1.9	4.80	±	0.09	1.9

Table D-5a. Inductively Coupled Plasma-Mass Spectrometry Data for the pH Stability Test: NC Apatite (Page 1 of 4)

	pH	Chromium				Manganese				Iron			
	of added water	ppb			StD%	ppb			StD%	ppb			StD%
Treatment 1	9	7.4	±	0.05	0.7	2.97	±	0.1	3.3	365	±	6.2	1.7
	8	6.3				1.42				300			
	7	7.2				3.68				277			
	6	5.2				1.17				303			
	5	7.4				1.45				364			
	48 hr	0.4	±	0.02	5.2	11.4	±	0.13	1.2	302	±	3	1
	Sat.	50.1	±	0.61	1.2	4.76	±	0	0.1	847	±	10.2	1.2
Treatment 2	9	17.3				1.65				322			
	8	15.3	±	0.13	0.9	1.61	±	0.05	3	355	±	9.4	2.7
	7	14.1				1.28				336			
	6	15.1	±	0.22	1.5	1.84	±	0.02	0.9	405	±	18.5	4.6
	5	15.9				1.83				413			
	48 hr	6.3	±	0.03	0.5	6.92	±	0.05	0.7	277	±	0.7	0.3
	Sat.	54	±	0.77	1.4	7.98	±	0.11	1.4	925	±	60.4	6.5
Treatment 3	9	2.3				1.8				312			
	8	1.5	±	0.02	1.1	1.62	±	0.01	0.5	341	±	3.7	1.1
	7	2.4				1.95				326			
	6	4.3				1.42				338			
	5	2.4	±	0.02	0.7	1.8	±	0.03	1.4	388	±	7.4	1.9
	48 hr	1.3	±	0.03	2.2	3.85	±	0.04	1.1	322	±	8.9	2.8
	Sat.	6.6	±	0.06	0.9	3.32	±	0.04	1.2	617	±	22	3.6
		Copper				Zinc				Arsenic			
Treatment 1	9	4.75	±	0.02	0.3	3.7	±	0.06	1.7	1.92	±	0.06	3.1
	8	3.15				17.8				1.63			
	7	4.72				6.34				1.77			
	6	3.06				16				1.42			
	5	3.06				2.06				1.89			
	48 hr	1.69	±	0.06	3.8	11.2	±	0.18	1.6	0.31	±	0.03	10.4
	Sat.	17.7	±	0.23	1.3	26.7	±	0.19	0.7	2.85	±	0.02	0.8
Treatment 2	9	5.67				28.1				2.75			
	8	3.38	±	0.03	1	5.33	±	0.12	2.3	1.93	±	0.09	4.6
	7	2.38				3.33				1.96			
	6	2.56	±	0.1	3.9	8.72	±	0.23	2.6	1.82	±	0.08	4.3
	5	3				12.3				2.14			
	48 hr	5.12	±	0.07	1.4	35.4	±	0.62	1.8	0.53	±	0.04	6.9
	Sat.	8.15	±	0.28	3.4	18.6	±	0.15	0.8	2.24	±	0.08	3.7
Treatment 3	9	5.46				10				1.73			
	8	3.5	±	0.02	0.6	4.99	±	0.1	2	1.58	±	0.06	3.5
	7	3.3				11				1.65			
	6	3.35				10.9				1.34			
	5	2.78	±	0.15	5.3	14.2	±	0.19	1.3	1.39	±	0.01	0.4
	48 hr	2.09	±	0.04	1.8	10.4	±	0.15	1.4	0.49	±	0.06	12.7
	Sat.	4.11	±	0.08	1.9	12.5	±	0.2	1.6	1.95	±	0.05	2.3

Table D-5a. Inductively Coupled Plasma-Mass Spectrometry Data for the pH Stability Test: NC Apatite (Page 2 of 4)

	pH of added water	Strontium ppb			StD%	Yttrium ppb			StD%	Silver ppb			StD%
Treatment 1	9	142	±	2.9	2	0.28	±	0.01	5.3	0.072	±	0.01	16.5
	8	119				na				<0.02			
	7	109				0.33				<0.02			
	6	117				na				<0.02			
	5	129				na				<0.02			
	48 hr	76.2	±	0.5	0.6	0.19	±	0.01	5.5	<0.02			
	Sat.	255	±	2.6	1	na				<0.02			
Treatment 2	9	109				na				<0.02			
	8	127	±	1.5	1.2	na				<0.02			
	7	124				na				<0.02			
	6	142	±	2.5	1.8	na				<0.02			
	5	136				na				<0.02			
	48 hr	62.3	±	0.5	0.8	1.17	±	0.08	6.9	<0.02			
	Sat.	264	±	4.3	1.6	na				<0.02			
Treatment 3	9	116				na				<0.02			
	8	128	±	0.7	0.6	na				<0.02			
	7	124				na				0.025			
	6	119				na				<0.02			
	5	135	±	1.5	1.1	na				<0.02			
	48 hr	85	±	1.4	1.7	0.44	±	0.03	7.3	<0.02			
	Sat.	221	±	1.9	0.9	na				<0.02			
		Cesium				**Barium**				**Lanthanum**			
Treatment 1	9	0.221	±	0	0.6	25.1	±	0.22	0.9	0.47	±	0.02	3.9
	8	0.21				23.4				<0.1			
	7	0.216				19.9				0.12			
	6	0.222				22.2				<0.1			
	5	0.201				24.9				<0.1			
	48 hr	0.204	±	0.01	3.4	13.3	±	0.31	2.4	<0.1			
	Sat.	0.276	±	0	0.9	30.7	±	0.22	0.7	0.62	±	0.09	14
Treatment 2	9	0.193				13.9				<0.1			
	8	0.191	±	0	1.3	19.9	±	0.34	1.7	<0.1			
	7	0.184	±	0	0	20				<0.1			
	6	0.194	±	0.01	2.8	23.5	±	0.29	1.2	<0.1			
	5	0.185				23.7				0.23			
	48 hr	0.253	±	0	0.8	10	±	0.18	1.8	0.27	±	0.02	7
	Sat.	0.195	±	0.01	3.6	43.7	±	0.74	1.7	0.68	±	0.08	11.4
Treatment 3	9	0.489				21.7				<0.1			
	8	0.222	±	0	0.4	23	±	0.38	1.7	<0.1			
	7	0.263				22.6				<0.1			
	6	0.205				23.6				<0.1			
	5	0.192	±	0	1.7	27.2	±	0.22	0.8	<0.1			
	48 hr	0.206	±	0.01	3.5	17	±	0.02	0.1	<0.1			
	Sat.	0.196	±	0	0.2	43.3	±	0.33	0.8	<0.1			

Table D-5a. Inductively Coupled Plasma-Mass Spectrometry Data for the pH Stability Test: NC Apatite (Page 3 of 4)

	pH	Cerium				Praeseodymium				Samarium			
	of added water	ppb			StD%	ppb			StD%	ppb			StD%
Treatment 1	9	0.25	±	0.01	2	0.07	±	0	4.5	0.1	±	0.03	33
	8	<0.1				<0.05				<0.05			
	7	0.31				<0.05				0.09			
	6	<0.1				<0.05				<0.05			
	5	<0.1				<0.05				<0.05			
	48 hr	0.17	±	0.03	15.6	<0.05				<0.05			
	Sat.	0.87	±	0.05	6	0.1	±	0.01	12.9	0.08	±	0.11	133
Treatment 2	9	0.1				<0.05				0.07			
	8	0.16	±	0.02	15.1	<0.05				<0.05			
	7	0.1				<0.05				<0.05			
	6	0.12	±	0.02	12.3	<0.05				0.08	±	0.07	88
	5	0.28				<0.05				<0.05			
	48 hr	0.38	±	0.03	7.7	<0.05				<0.05			
	Sat.	1.35	±	0.05	3.6	0.24	±	0.01	5	0.11	±	0.04	36
Treatment 3	9	0.13				<0.05				<0.05			
	8	<0.1				<0.05				0.06	±	0.05	87
	7	<0.1				<0.05				<0.05			
	6	0.18				<0.05				0.09			
	5	<0.1				<0.05				<0.05			
	48 hr	0.15	±	0	1.9	<0.05				<0.05			
	Sat.	<0.1				<0.05				0.07	±	0.08	111
		Europium				Gadolinium				Dysprosium			
Treatment 1	9	0.061	±	0.04	73	0.08	±	0.01	14	0.11	±	0.02	23
	8	0.083				0.04				0.13			
	7	0.067				<0.02				<0.05			
	6	<0.05				<0.02				<0.05			
	5	0.092				0.03				0.09			
	48 hr	<0.05				0.05	±	0.01	25	<0.05			
	Sat.	0.097	±	0.02	23	0.09	±	0.04	43	0.32	±	0.12	38
Treatment 2	9	<0.05				<0.02				0.06			
	8	0.054	±	0.03	62	0.06	±	0.03	42	<0.05			
	7	<0.05				0.03				<0.05			
	6	0.055	±	0.04	72	0.03	±	0.03	92	<0.05			
	5	<0.05				0.04				0.25			
	48hr	0.055	±	0.01	10	0.06	±	0.04	58	1.28	±	0.19	15
	Sat.	0.143	±	0.01	6	0.2	±	0.01	7	0.89	±	0.14	16
Treatment 3	9	0.065				0.06				0.19			
	8	0.053	±	0.03	63	0.05	±	0.01	16	<0.05			
	7	<0.05				<0.02				0.08			
	6	<0.05				0.04				0.06			
	5	0.051	±	0.03	49	0.05	±	0.04	72	0.14	±	0.08	56
	48 hr	<0.05				0.09	±	0.05	51	0.43	±	0.04	10
	Sat.	0.07	±	0.01	7	0.03	±	0.05	151	0.13	±	0.11	83

Table D-5a. Inductively Coupled Plasma-Mass Spectrometry Data for the pH Stability Test: NC Apatite (Page 4 of 4)

	pH of added water	Holmium ppb			StD%	Erbium ppb			StD%	Lead ppb			StD%
Treatment 1	9	<0.02				<0.05				<0.1			
	8	<0.02				<0.05				<0.1			
	7	<0.02				<0.05				<0.1			
	6	<0.02				0.06				0.11			
	5	<0.02				<0.05				<0.1			
	48 hr	<0.02				<0.05				0.14	±	0.01	5.4
	Sat.	0.028	±	0.02	75	<0.05				0.73	±	0.02	2
Treatment 2	9	<0.02				<0.05				0.34			
	8	<0.02				<0.05				<0.1			
	7	<0.02				<0.05				0.13			
	6	<0.02				0.06	±	0.03	45	<0.1			
	5	0.041				0.06				0.23			
	48 hr	0.07	±	0.01	18	<0.05				2.03	±	0.08	4.2
	Sat.	0.056	±	0.01	20	0.06	±	0.03	52	0.92	±	0.01	1.2
Treatment 3	9	<0.02				<0.05				0.17			
	8	<0.02				<0.05				<0.1			
	7	<0.02				<0.05				0.19			
	6	<0.02				<0.05				0.32			
	5	<0.02				<0.05				0.18	±	0.03	16.5
	48 hr	<0.02				<0.05				0.5	±	0.01	1.2
	Sat.	<0.02				0.08	±	0.06	72	0.15	±	0.03	20.3

Table D-5b. Inductively Coupled Plasma-Mass Spectrometry Data for the pH Stability Test: Bone Char (Page 1 of 4)

	pH	Chromium				Manganese				Iron			
	of added water	ppb			StD%	ppb			StD%	ppb			StD%
Treatment 1	9	11.4	±	0.21	1.8	8.21	±	0.05	0.6	197	±	3.7	1.9
	8	10.5	±	0.09	0.9	0.85	±	0.02	2.1	17	±	1.2	6.9
	7	8.0	±	0.08	1.0	1.69	±	0.01	0.7	59	±	0.9	1.5
	6	7.7	±	0.12	1.5	3.25	±	0.04	1.2	78	±	2.2	2.9
	5	7.2	±	0.20	2.7	0.42	±	0.00	0.8	12	±	2.4	20.1
	48 hr	0.7	±	0.01	1.2	0.77	±	0.01	1.6	103	±	0.7	0.6
	Satur	63.4	±	1.0	1.6	2.72	±	0.01	0.5	120	±	5.4	4.5
Treatment 2	9	19.5	±	0.19	1.0	0.64	±	0.02	2.7	13	±	0.8	6.3
	8	14.2	±	0.22	1.5	0.93	±	0.01	1.2	41	±	0.8	1.9
	7	12.4	±	0.18	1.5	0.87	±	0.01	1.1	17	±	2.2	12.4
	6	12.1	±	0.15	1.3	0.51	±	0.01	1.8	17	±	1.8	10.2
	5	15.6	±	0.13	0.8	0.74	±	0.02	2.3	11	±	1.7	15.2
	48 hr	1.6	±	0.05	3.1	1.58	±	0.02	1.3	69	±	2.1	3.0
	Sat.	28.8	±	0.33	1.1	2.20	±	0.02	1.1	137	±	2.5	1.8
Treatment 3	9	6.5	±	0.10	1.5	0.68	±	0.04	6.1	<10			
	8	7.1	±	0.07	0.9	0.71	±	0.00	0.6	19	±	1.0	5.4
	7	6.2	±	0.05	0.9	0.57	±	0.02	3.3	14	±	1.9	14.1
	6	7.8	±	0.11	1.4	0.63	±	0.01	2.3	17	±	3.3	19.5
	5	7.3	±	0.07	1.0	0.63	±	0.03	4.8	26	±	1.5	5.8
	48 hr	0.9	±	0.03	3.6	1.55	±	0.01	0.7	189	±	1.0	0.5
	Sat.	15.8	±	0.04	0.3	0.76	±	0.01	1.4	55	±	0.5	0.8
		Copper				Zinc				Arsenic			
Treatment 1	9	8.20	±	0.07	0.8	1.97	±	0.22	10.9	2.09	±	0.04	2.1
	8	6.71	±	0.16	2.4	19.9	±	0.20	1.0	1.83	±	0.05	2.9
	7	5.55	±	0.14	2.5	6.19	±	0.27	4.4	1.55	±	0.06	3.6
	6	3.09	±	0.06	1.8	4.18	±	0.11	2.7	1.30	±	0.06	4.6
	5	2.62	±	0.05	2.0	1.34	±	0.12	8.7	1.26	±	0.05	4.3
	48 hr	1.34	±	0.08	6.0	6.13	±	0.14	2.3	0.17	±	0.03	15.8
	Sat.	6.32	±	0.11	1.7	2.47	±	0.06	2.5	3.03	±	0.08	2.6
Treatment 2	9	3.87	±	0.08	2.1	20.3	±	0.18	0.9	1.91	±	0.02	0.9
	8	2.55	±	0.33	12.8	7.29	±	0.10	1.4	1.60	±	0.05	2.9
	7	1.79	±	0.06	3.4	3.81	±	0.18	4.6	1.31	±	0.01	0.6
	6	1.28	±	0.02	1.2	2.47	±	0.06	2.5	1.35	±	0.10	7.2
	5	1.82	±	0.06	3.4	6.36	±	0.13	2.0	1.44	±	0.07	4.6
	48 hr	0.99	±	0.04	3.7	6.81	±	0.11	1.6	0.30	±	0.01	4.9
	Sat.	2.07	±	0.02	0.9	12.2	±	0.23	1.9	1.47	±	0.04	2.7
Treatment 3	9	1.84	±	0.12	6.5	2.74	±	0.14	5.2	1.19	±	0.04	3.6
	8	1.41	±	0.06	4.2	7.11	±	0.11	1.6	0.98	±	0.05	4.7
	7	0.75	±	0.05	6.4	1.37	±	0.05	3.7	0.96	±	0.02	1.6
	6	0.79	±	0.02	1.9	4.02	±	0.03	0.8	1.03	±	0.01	1.1
	5	1.43	±	0.01	1.0	6.09	±	0.16	2.6	0.86	±	0.05	5.6
	48 hr	1.32	±	0.05	3.9	5.43	±	0.18	3.4	0.17	±	0.01	5.7
	Sat.	0.77	±	0.06	7.8	1.56	±	0.25	15.8	1.03	±	0.06	5.8

Table D-5b. Inductively Coupled Plasma-Mass Spectrometry Data for the pH Stability Test: Bone Char (Page 2 of 4)

	pH	Strontium		Yttrium		Silver	
	of added water	ppb	StD%	ppb	StD%	ppb	StD%
Treatment 1	9	12.3 ± 0.23	1.9	0.91 ± 0.04	4.9	0.452 ± 0.00	1.6
	8	12.5 ± 0.12	0.9	1.41 ± 0.14	10.2	0.282 ± 0.03	12.2
	7	10.8 ± 0.12	1.1	338 ± 4	1.3	0.205 ± 0.00	3.7
	6	14.6 ± 0.07	0.5	1.15 ± 0.15	13.3	0.160 ± 0.01	6.2
	5	14.8 ± 0.28	1.9	81.7 ± 1.2	1.5	0.137 ± 0.02	18.8
	48 hr	44.3 ± 0.14	0.3	7.7 ± 0.12	1.5	0.026 ± 0.00	4.5
	Sat.	58.3 ± 0.48	0.8	0.58 ± 0.06	9.5	0.462 ± 0.02	5.7
Treatment 2	9	10.7 ± 0.21	1.9	0.47 ± 0.03	5.7	0.229 ± 0.03	13.2
	8	13.7 ± 0.24	1.7	0.43 ± 0.01	2.7	0.171 ± 0.02	13.2
	7	12.7 ± 0.19	1.5	0.39 ± 0.04	10.7	0.104 ± 0.00	6.6
	6	14.6 ± 0.06	0.4	0.20 ± 0.03	13.3	0.086 ± 0.00	5.4
	5	13.2 ± 0.11	0.8	0.40 ± 0.03	7.1	0.116 ± 0.01	14.8
	48 hr	30.1 ± 0.20	0.7	0.37 ± 0.01	2.9	<0.02	
	Sat.	36.6 ± 0.04	0.1	0.42 ± 0.03	7.9	0.155 ± 0.02	13.3
Treatment 3	9	12.0 ± 0.11	0.9	0.17 ± 0.01	3.6	0.125 ± 0.01	12.1
	8	11.5 ± 0.11	1.0	0.23 ± 0.02	9.8	0.076 ± 0.02	28.5
	7	12.5 ± 0.10	0.8	0.16 ± 0.03	17.6	0.060 ± 0.00	12.9
	6	12.2 ± 0.11	0.9	0.29 ± 0.03	10.5	0.038 ± 0.00	15.1
	5	11.1 ± 0.03	0.2	0.21 ± 0.01	5.7	0.040 ± 0.00	10.0
	48hr	65.3 ± 0.28	0.4	0.06 ± 0.01	14.5	<0.02	
	Sat.	27.6 ± 0.13	0.5	0.13 ± 0.01	9.3	0.055 ± 0.00	7.0
		Cesium		**Barium**		**Lanthanum**	
Treatment 1	9	0.214 ± 0.00	2.2	6.55 ± 0.11	1.7	0.84 ± 0.06	7.7
	8	0.190 ± 0.00	2.3	6.41 ± 0.09	1.4	<0.1	
	7	0.249 ± 0.00	0.6	5.84 ± 0.12	2.1	0.21 ± 0.01	3.5
	6	0.197 ± 0.00	1.9	7.09 ± 0.11	1.5	0.34 ± 0.03	8.7
	5	0.194 ± 0.01	5.0	6.90 ± 0.13	2.0	<0.1	
	48 hr	0.210 ± 0.00	0.9	12.8 ± 0.20	1.6	<0.1	
	Sat.	0.194 ± 0.00	2.0	26.4 ± 0.37	1.4	0.21 ± 0.05	24.2
Treatment 2	9	0.514 ± 0.00	1.3	5.69 ± 0.06	1.1	<0.1	
	8	0.200 ± 0.00	1.0	6.78 ± 0.03	0.5	0.14 ± 0.04	26.5
	7	0.186 ± 0.00	1.2	6.15 ± 0.05	0.8	0.28 ± 0.03	9.4
	6	0.187 ± 0.00	0.2	7.01 ± 0.10	1.4	<0.1	
	5	0.186 ± 0.00	0.8	6.82 ± 0.05	0.8	<0.1	
	48 hr	0.186 ± 0.00	1.7	8.81 ± 0.07	0.8	0.21 ± 0.02	8.7
	Sat.	0.194 ± 0.00	2.7	18.3 ± 0.14	0.7	0.28 ± 0.02	8.5
Treatment 3	9	0.199 ± 0.00	2.9	6.73 ± 0.09	1.3	<0.1	
	8	0.194 ± 0.00	2.1	6.25 ± 0.09	1.4	<0.1	
	7	0.204 ± 0.00	0.6	6.84 ± 0.09	1.3	<0.1	
	6	0.189 ± 0.00	1.0	7.08 ± 0.08	1.1	<0.1	
	5	0.202 ± 0.00	0.2	6.01 ± 0.03	0.5	0.19 ± 0.02	10.4
	48hr	0.194 ± 0.00	2.2	20.3 ± 0.20	1.0	<0.1	
	Sat.	0.199 ± 0.00	1.6	15.7 ± 0.10	0.6	<0.1	

Table D-5b. Inductively Coupled Plasma-Mass Spectrometry Data for the pH Stability Test: Bone Char (Page 3 of 4)

	pH	Cerium				Praeseodymium				Samarium			
	of added water	ppb			StD%	ppb			StD%	ppb			StD%
Treatment 1	9	1.7	±	0.07	4	0.21	±	0.01	5	0.25	±	0.13	51
	8	0.12	±	0.03	23.9	<0.05				<0.05			
	7	0.4	±	0.02	6.2	<0.05				0.14	±	0.09	65
	6	0.91	±	0.02	2.6	0.09	±	0.02	20.9	0.1	±	0.06	56
	5	<0.1				<0.05				0.1	±	0.04	41
	48 hr	<0.1				<0.05				0.14	±	0.09	66
	Sat.	0.51	±	0.06	12.5	<0.05				0.16	±	0.05	28
Treatment 2	9	0.1	±	0.03	30.1	<0.05				0.11	±	0.09	83
	8	0.23	±	0.02	9.1	<0.05				0.11	±	0.08	68
	7	0.31	±	0.05	15.6	0.05	±	0.02	41.5	<0.05			
	6	0.11	±	0.02	15.4	<0.05				<0.05			
	5	0.13	±	0.01	7.1	<0.05				<0.05			
	48 hr	0.34	±	0.06	17.5	<0.05				<0.05			
	Sat.	0.44	±	0.03	7	0.08	±	0.03	37.6	0.1	±	0.06	64
Treatment 3	9	<0.1				<0.05				<0.05			
	8	0.18	±	0.1	54.4	<0.05				0.07	±	0.02	28
	7	<0.1				<0.05				<0.05			
	6	0.13	±	0.01	6	<0.05				0.1	±	0.03	31
	5	0.24	±	0.01	5.4	0.05	±	0.02	27.4	<0.05			
	48 hr	<0.1				<0.05				<0.05			
	Sat.	0.11	±	0.01	13.5	<0.05				<0.05			
		Europium				Gadolinium				Dysprosium			
Treatment 1	9	0.064	±	0.02	23	0.61	±	0.05	8	0.13	±	0.05	38
	8	<0.05				0.62	±	0.13	21	<0.05			
	7	<0.05				2.29	±	0.26	11	0.15	±	0.06	38
	6	<0.05				0.48	±	0.09	18	0.06	±	0.04	65
	5	<0.05				0.95	±	0.12	13	<0.05			
	48 hr	0.058	±	0.03	55	0.21	±	0.05	25	0.06	±	0.04	67
	Sat.	0.09	±	0	4	0.38	±	0.09	22	<0.05			
Treatment 2	9	<0.05				0.37	±	0.07	20	0.07	±	0.03	50
	8	<0.05				0.46	±	0.11	23	<0.05			
	7	<0.05				0.43	±	0.08	20	0.1	±	0.03	26
	6	<0.05				0.23	±	0.02	11	<0.05			
	5	0.092	±	0.01	8	0.44	±	0.05	10	0.11	±	0.11	99
	48 hr	<0.05				0.16	±	0.09	58	0.19	±	0.07	38
	Sat.	0.085	±	0.01	16	0.36	±	0.01	4	0.41	±	0.01	3
Treatment 3	9	<0.05				0.15	±	0.05	33	0.05	±	0.04	75
	8	<0.05				0.31	±	0.07	22	0.17	±	0.06	38
	7	0.052	±	0.01	9	0.28	±	0.13	49	<0.05			
	6	<0.05				0.23	±	0.05	21	0.14	±	0.06	45
	5	0.053	±	0.03	56	0.19	±	0.01	7	0.31	±	0.03	8
	48 hr	0.056	±	0.04	68	0.05	±	0.02	38	0.08	±	0.09	111
	SSat.	<0.05				0.1	±	0.01	12	0.08	±	0.04	44

Table D-5b. Inductively Coupled Plasma-Mass Spectrometry Data for the pH Stability Test: Bone Char (Page 4 of 4)

	pH	Holmium				Erbium				Lead			
	of added water	ppb			StD%	ppb			StD%	ppb			StD%
Treatment 1	9	0.067	±	0.02	31	0.16	±	0.06	34	0.74	±	0.01	1.3
	8	<0.02				<0.05				0.39	±	0.03	7.2
	7	0.031	±	0.02	66	0.06	±	0.02	30	0.58	±	0.02	4
	6	<0.02				0.06	±	0.02	36	0.37	±	0.01	3
	5	<0.02				0.06	±	0.06	92	0.27	±	0.02	5.9
	48 hr	0.021	±	0.02	79	0.07	±	0.01	16	0.16	±	0.02	11.6
	Sat.	<0.02				0.09	±	0.02	17	0.43	±	0.01	3.3
Treatment 2	9	<0.02				<0.05				0.36	±	0.01	2.4
	8	<0.02				<0.05				0.41	±	0.03	6
	7	<0.02				<0.05				0.33	±	0.02	5.5
	6	<0.02				<0.05				0.19	±	0.02	7.7
	5	<0.02				<0.05				0.4	±	0.03	6.1
	48 hr	0.033	±	0.03	92	<0.05				0.45	±	0.04	9.4
	Sat.	<0.02				0.06	±	0.03	61	0.89	±	0.02	1.9
Treatment 3	9	<0.02				<0.05				0.12	±	0.01	11
	8	0.025	±	0.01	24	<0.05				0.43	±	0.02	5.6
	7	<0.02				<0.05				0.12	±	0.01	6.3
	6	0.023	±	0.01	30	0.05	±	0.03	50	0.3	±	0	0.6
	5	0.023	±	0.02	69	<0.05				0.46	±	0.02	3.7
	48 hr	<0.02				<0.05				0.11	±	0.02	15.1
	Sat.	0.04	±	0.02	40	0.06	±	0.02	33	0.16	±	0.02	9.2

Table D-5c. Inductively Coupled Plasma-Mass Spectrometry Data for the pH Stability Test: Hydroxyapatite (Page 1 of 4)

	pH of added water	Chromium ppb			StD%	Manganese ppb			StD%	Iron ppb			StD%
Treatment 1	9	10.1	±	0.16	1.6	1.68	±	0.02	1.4	467	±	7.5	1.6
	8	13.8	±	0.36	2.6	1.46	±	0.02	1.6	407	±	20.4	5.0
	7	14.1	±	0.31	2.2	1.60	±	0.01	0.8	398	±	5.3	1.3
	6	15.0	±	0.12	0.8	1.61	±	0.05	3.1	468	±	8.3	1.8
	5	13.5	±	0.13	1.0	1.46	±	0.02	1.1	494	±	7.8	1.6
	48 hr	0.3	±	0.02	8.5	2.06	±	0.03	1.7	349	±	2.9	0.8
	Satur	35.8				2.39				669			
Treatment 2	9	18.8	±	0.05	0.2	1.19	±	0.01	0.9	403	±	4.1	1.0
	8	20.2	±	0.10	0.5	1.76	±	0.04	2.5	462	±	8.2	1.8
	7	19.0	±	0.32	1.7	1.62	±	0.01	0.3	463	±	3.9	0.8
	6	18.4	±	0.28	1.5	1.73	±	0.03	1.6	468	±	10.5	2.3
	5	18.3	±	0.19	1.0	1.51	±	0.03	1.9	467	±	4.7	1.0
	48 hr	7.4	±	0.12	1.7	1.87	±	0.01	0.6	299	±	2.2	0.7
	Satur	38.2				3.62				614			
Treatment 3	9	7.8	±	0.09	1.2	1.39	±	0.02	1.4	341	±	5.6	1.7
	8	7.3	±	0.11	1.5	1.05	±	0.00	0.1	350	±	6.4	1.8
	7	7.0	±	0.10	1.4	1.24	±	0.01	1.1	386	±	6.5	1.7
	6	6.8	±	0.09	1.3	1.32	±	0.01	0.5	391	±	12.9	3.3
	5	6.7	±	0.03	0.4	1.45	±	0.02	1.6	425	±	1.8	0.4
	48 hr	1.9	±	0.01	0.3	1.12	±	0.01	1.2	291	±	0.7	0.2
	Satur	10.4	±	0.05	0.4	1.42	±	0.01	1.0	348	±	5.4	1.5
		Copper				**Zinc**				**Arsenic**			
Treatment 1	9	1.39	±	0.03	2.5	9.85	±	0.30	3.0	0.11	±	0.00	2.8
	8	0.89	±	0.02	2.1	3.67	±	0.13	3.5	0.15	±	0.01	6.7
	7	2.00	±	0.01	0.4	2.98	±	0.09	2.9	0.13	±	0.00	3.6
	6	1.24	±	0.10	8.0	19.2	±	0.47	2.4	0.14	±	0.01	8.4
	5	0.98	±	0.06	6.1	4.49	±	0.05	1.2	0.14	±	0.00	1.9
	48 hr	0.47	±	0.05	10.4	1.74	±	0.15	8.7	0.12	±	0.02	13.4
	Satur	4.34				10.3				0.43			
Treatment 2	9	1.83	±	0.04	2.3	2.73	±	0.08	2.8	0.23	±	0.01	3.5
	8	2.01	±	0.04	2.1	8.35	±	0.24	2.8	0.22	±	0.02	7.9
	7	2.34	±	0.02	0.9	2.03	±	0.06	3.0	0.24	±	0.02	6.9
	6	1.09	±	0.06	5.7	6.40	±	0.21	3.2	0.21	±	0.01	2.6
	5	1.63	±	0.07	4.2	2.82	±	0.07	2.3	0.21	±	0.04	17.2
	48 hr	0.94	±	0.04	4.6	6.04	±	0.04	0.7	0.16	±	0.03	17.7
	Satur	5.50				64.0	±	0.00	0.0	0.59	±	0.00	0.0
Treatment 3	9	1.84	±	0.04	2.4	5.94	±	0.06	1.0	0.26	±	0.03	12.2
	8	1.33	±	0.09	7.1	6.58	±	0.04	0.6	0.24	±	0.03	14.0
	7	1.13	±	0.02	1.5	1.57	±	0.11	7.3	0.22	±	0.03	14.1
	6	2.12	±	0.05	2.1	2.98	±	0.15	4.9	0.19	±	0.02	9.8
	5	1.09	±	0.02	1.8	1.78	±	0.05	3.0	0.21	±	0.02	8.3
	48 hr	1.31	±	0.08	6.3	8.05	±	0.10	1.2	0.14	±	0.03	21.0
	Satur	3.15	±	0.13	4.0	8.28	±	0.17	2.0	0.43	±	0.02	4.0

Table D-5c. Inductively Coupled Plasma-Mass Spectrometry Data for the pH Stability Test: Hydroxyapatite (Page 2 of 4)

	pH of added water	Strontium ppb			StD%	Yttrium ppb			StD%	Silver ppb			StD%
Treatment 1	9	88.3	±	0.54	0.6	<0.05				<0.02			
	8	83.9	±	0.64	0.8	<0.05				<0.02			
	7	76.3	±	0.38	0.5	<0.05				<0.02			
	6	90.8	±	0.65	0.7	0.07	±	0.02	36.7	<0.02			
	5	93.7	±	0.28	0.3	0.07	±	0.01	10.9	<0.02			
	48 hr	55.9	±	0.50	0.9	<0.05				<0.02			
	Satur	118					not			<0.02			
Treatment 2	9	81.1	±	0.83	1.0	0.17	±	0.02	14.8	<0.02			
	8	90.6	±	0.70	0.8	0.35	±	0.01	2.6	<0.02			
	7	92.1	±	0.01	0.0		not			<0.02			
	6	90.7	±	0.82	0.9	0.14	±	0.01	9.5	<0.02			
	5	90.3	±	0.30	0.3	0.09	±	0.02	19.4	<0.02			
	48 hr	41.4	±	0.15	0.4	0.15	±	0.04	24.2	<0.02			
	Satur	103	±	0.00	0.0		not			<0.02			
Treatment 3	9	69.4	±	0.24	0.3	0.14	±	0.01	8.3	0.028	±	0.00	23.7
	8	69.6	±	0.19	0.3	0.17	±	0.02	12.7	<0.02			
	7	78.7	±	0.41	0.5	0.09	±	0.01	8.8	<0.02			
	6	76.8	±	0.30	0.4	0.07	±	0.02	23.7	<0.02			
	5	82.6	±	0.42	0.5	0.07	±	0.01	10.6	0.038	±	0.00	14.5
	48 hr	49.4	±	0.18	0.4	0.10	±	0.02	24.8	<0.02			
	Satur	62.0	±	0.19	0.3	0.09	±	0.01	11.1	0.042	±	0.00	20.1
		Cesium				**Barium**				**Lanthanum**			
Treatment 1	9	0.189	±	0.00	0.4	22.2	±	0.02	0.1	<0.1			
	8	0.202	±	0.00	1.5	23.8	±	0.19	0.8	<0.1			
	7	0.222	±	0.00	0.4	20.9	±	0.14	0.7	<0.1			
	6	0.193	±	0.00	2.8	27.2	±	0.29	1.1	<0.1			
	5	0.193	±	0.00	1.5	27.7	±	0.13	0.5	<0.1			
	48 hr	0.193	±	0.00	0.5	13.1	±	0.13	1.0	<0.1			
	Satur	0.201	±	0.00	0.0	31.3				0.11			
Treatment 2	9	0.192	±	0.00	0.6	21.9	±	0.10	0.5	<0.1			
	8	0.196	±	0.00	1.5	24.9	±	0.17	0.7	<0.1			
	7	0.194	±	0.00	0.8	25.4	±	0.15	0.6	<0.1			
	6	0.190	±	0.00	0.9	25.0	±	0.11	0.4	<0.1			
	5	0.199	±	0.00	1.2	29.2	±	0.08	0.3	<0.1			
	48hr	0.194	±	0.00	0.2	9.72	±	0.02	0.2	<0.1			
	Satur	0.195	±	0.00	0.0	29.8				0.21			
Treatment 3	9	0.194	±	0.00	0.6	20.8	±	0.04	0.2	<0.1			
	8	0.192	±	0.00	1.6	19.6	±	0.25	1.3	<0.1			
	7	0.213	±	0.00	1.8	22.7	±	0.29	1.3	<0.1			
	6	0.197	±	0.00	1.3	22.3	±	0.15	0.7	<0.1			
	5	0.203	±	0.00	1.3	24.3	±	0.10	0.4	<0.1			
	48 hr	0.235	±	0.00	1.0	12.4	±	0.06	0.4	<0.1			
	Satur	0.200	±	0.00	1.0	3.79	±	0.07	1.8	<0.1			

Table D-5c. Inductively Coupled Plasma-Mass Spectrometry Data for the pH Stability Test: Hydroxyapatite (Page 3 of 4)

	pH of added water	Cerium ppb			StD%	Praeseodymium ppb			StD%	Samarium ppb			StD%
Treatment 1	9	<0.1				<0.05				<0.05			
	8	<0.1				<0.05				0.07	±	0.05	69
	7	<0.1				<0.05				<0.05			
	6	<0.1				<0.05				<0.05			
	5	<0.1				<0.05				0.07	±	0.04	62
	48 hr	<0.1				<0.05				<0.05			
	Satur	0.23				0.06				<0.05			
Treatment 2	9	<0.1				<0.05				0.08	±	0.02	30
	8	<0.1				<0.05				0.07	±	0.05	70
	7	<0.1				<0.05				<0.05			
	6	0.10	±	0.00	3.5	<0.05				0.07	±	0.05	72
	5	<0.1				<0.05				<0.05			
	48 hr	0.13	±	0.02	16.3	<0.05				<0.05			
	Satur	0.30				0.07				0.10			
Treatment 3	9	<0.1				<0.05				0.09	±	0.03	31
	8	<0.1				<0.05				<0.05			
	7	<0.1				<0.05				<0.05			
	6	<0.1				<0.05				0.06	±	0.02	43
	5	<0.1				<0.05				0.05	±	0.01	23
	48 hr	<0.1				<0.05				<0.05			
	Satur	<0.1				<0.05				0.08	±	0.01	19
		Europium				**Gadolinium**				**Dysprosium**			
Treatment 1	9	<0.05				0.06	±	0.05	81	<0.05			
	8	<0.05				0.14	±	0.01	5	<0.05			
	7	0.064	±	0.02	44	0.04	±	0.02	49	<0.05			
	6	0.072	±	0.03	44	<0.02				<0.05			
	5	<0.05				0.03	±	0.05	155	<0.05			
	48 hr	<0.05				0.06	±	0.02	44	<0.05			
	Satur	0.077				0.11				<0.05			
Treatment 2	9	0.056	±	0.01	28	<0.02				<0.05			
	8	0.067	±	0.00	11	0.07	±	0.01	14	0.10	±	0.01	13
	7	0.052	±	0.00	6	0.09	±	0.09	103	<0.05			
	6	0.056	±	0.03	59	0.07	±	0.03	42	<0.05			
	5	0.056	±	0.02	46	<0.02				<0.05			
	48 hr	<0.05				0.02	±	0.02	97	0.10	±	0.08	78
	Satur	0.112				0.08				0.53			
Treatment 3	9	<0.05				0.02	±	0.02	115	0.09	±	0.01	15
	8	<0.05				0.06	±	0.02	34	0.19	±	0.07	36
	7	<0.05				0.04	±	0.03	83	<0.05			
	6	0.069	±	0.02	38	0.09	±	0.05	51	<0.05			
	5	0.061	±	0.00	14	0.06	±	0.03	52	<0.05			
	48 hr	<0.05				0.05	±	0.01	29	0.07	±	0.01	17
	Satur	<0.05				0.16	±	0.03	19	<0.05			

Table D-5c. Inductively Coupled Plasma-Mass Spectrometry Data for the pH Stability Test: Hydroxyapatite (Page 4 of 4)

	pH	Holmium				Erbium				Lead			
	of added water	ppb			StD%	ppb			StD%	ppb			StD%
Treatment 1	9	<0.02				<0.05				<0.1			
	8	<0.02				<0.05				0.12	±	0.00	5.0
	7	<0.02				<0.05				0.16	±	0.01	11.9
	6	<0.02				<0.05				0.13	±	0.01	13.7
	5	<0.02				<0.05				<0.1			
	48 hr	<0.02				<0.05				<0.1			
	Satur	<0.02				<0.05				<0.1			
Treatment 2	9	<0.02				<0.05				<0.1			
	8	<0.02				<0.05				0.29	±	0.02	9.0
	7	<0.02				<0.05				<0.1			
	6	<0.02				<0.05				<0.1			
	5	<0.02				<0.05				<0.1			
	48 hr	<0.02				<0.05				0.64	±	0.05	8.1
	Satur	0.029				<0.05				1.02			
Treatment 3	9	<0.02				<0.05				<0.1			
	8	<0.02				<0.05				0.21	±	0.01	6.5
	7	<0.02				<0.05				<0.1			
	6	<0.02				<0.05				<0.1			
	5	<0.02				<0.05				<0.1			
	48 hr	0.021	±	0.01	50	<0.05				0.18	±	0.01	9.5
	Satur	<0.02				0.06	±	0.01	19	0.16	±	0.01	10.2

Table D-5d. Inductively Coupled Plasma-Mass Spectrometry Data for the pH Stability Test: Clinoptilolite (Page 1 of 4)

	pH	Chromium		Manganese		Iron	
	of added water	ppb	StD%	ppb	StD%	ppb	StD%
Treatment 1	9	8.0 ± 0.13	1.6	12.6 ± 0.11	0.9	409 ± 1.2	0.3
	8	5.0 ± 0.08	1.6	5.18 ± 0.01	0.3	193 ± 1.6	0.8
	7	4.7 ± 0.08	1.8	12.5 ± 0.21	1.6	429 ± 6.4	1.5
	6	4.5 ± 0.05	1.0	4.88 ± 0.05	1.0	183 ± 0.8	0.4
	5	4.9 ± 0.02	0.4	4.56 ± 0.01	0.2	226 ± 1.2	0.5
	48 hr	0.9 ± 0.03	3.2	34.1 ± 0.17	0.5	923 ± 7.3	0.8
	Sat.	22.2 ± 0.14	0.6	16.7 ± 0.16	1.0	557 ± 6.1	1.1
Treatment 2	9	10.8 ± 0.07	0.6	3.86 ± 0.06	1.7	145 ± 4.3	3.0
	8	9.7 ± 0.03	0.3	1.93 ± 0.04	2.2	92 ± 1.6	1.7
	7	9.8 ± 0.07	0.7	2.52 ± 0.04	1.5	110 ± 1.5	1.3
	6	10.1 ± 0.10	1.0	3.03 ± 0.04	1.4	119 ± 0.9	0.8
	5	10.1 ± 0.07	0.7	3.41 ± 0.03	0.8	130 ± 0.8	0.6
	48 hr	2.2 ± 0.04	1.9	55.6 ± 0.14	0.2	1406 ± 2.5	0.2
	Sat.	50.9 ± 0.31	0.6	20.1 ± 0.11	0.6	590 ± 5.9	1.0
Treatment 3	9	1.5 ± 0.03	1.9	3.35 ± 0.02	0.7	124 ± 1.6	1.3
	8	2.9 ± 0.10	3.4	2.89 ± 0.02	0.8	106 ± 0.5	0.5
	7	2.0 ± 0.02	1.2	9.17 ± 0.02	0.2	195 ± 3.4	1.8
	6	1.8 ± 0.03	1.7	2.72 ± 0.05	1.9	90 ± 0.7	0.8
	5	1.4 ± 0.14	9.8	3.38 ± 0.38	11.1	168 ± 25.9	15.4
	48 hr	3.1 ± 0.03	0.8	28.1 ± 0.07	0.3	754 ± 13.0	1.7
	Sat.	14.0 ± 0.03	0.2	33.1 ± 0.02	0.1	796 ± 4.8	0.6
		Copper		**Zin**		**Arsenic**	
Treatment 1	9	15.2 ± 0.24	1.6	32.4 ± 0.32	1.0	21.7 ± 0.49	2.3
	8	6.12 ± 0.08	1.3	3.79 ± 0.10	2.6	11.3 ± 0.07	0.6
	7	7.53 ± 0.10	1.3	3.49 ± 0.03	0.9	9.99 ± 0.34	3.4
	6	5.84 ± 0.03	0.6	4.05 ± 0.05	1.2	12.7 ± 0.23	1.8
	5	5.69 ± 0.06	1.1	5.70 ± 0.10	1.7	11.9 ± 0.33	2.8
	48 hr	3.80 ± 0.03	0.7	12.6 ± 0.15	1.2	1.25 ± 0.09	7.3
	Sat.	14.8 ± 0.21	1.4	42.5 ± 1.47	3.4	20.5 ± 0.64	3.1
Treatment 2	9	7.58 ± 0.12	1.6	15.1 ± 0.05	0.3	14.7 ± 0.18	1.2
	8	4.54 ± 0.06	1.2	1.98 ± 0.09	4.5	10.2 ± 0.19	1.8
	7	5.64 ± 0.07	1.2	1.69 ± 0.08	4.8	12.4 ± 0.35	2.9
	6	4.48 ± 0.06	1.4	7.59 ± 0.20	2.7	10.6 ± 0.13	1.2
	5	5.05 ± 0.04	0.9	4.11 ± 0.16	4.0	12.4 ± 0.37	3.0
	48 hr	5.77 ± 0.12	2.1	14.1 ± 0.19	1.3	1.47 ± 0.14	9.8
	Sat.	14.6 ± 0.10	0.7	16.5 ± 0.12	0.7	37.5 ± 0.46	1.2
Treatment 3	9	8.11 ± 0.12	1.5	2.85 ± 0.23	8.0	11.5 ± 0.25	2.2
	8	5.37 ± 0.04	0.7	7.51 ± 0.30	4.0	8.44 ± 0.19	2.3
	7	5.54 ± 0.16	2.9	5.68 ± 0.12	2.0	9.77 ± 0.18	1.9
	6	4.72 ± 0.10	2.1	6.81 ± 0.19	2.8	9.76 ± 0.19	1.9
	5	5.08 ± 0.61	12.0	7.69 ± 1.30	16.9	9.07 ± 1.23	13.5
	48 hr	4.02 ± 0.01	0.3	8.04 ± 0.11	1.4	1.68 ± 0.05	2.7
	Sat.	15.1 ± 0.12	0.8	13.0 ± 0.26	2.0	33.6 ± 0.53	1.6

Table D-5d. Inductively Coupled Plasma-Mass Spectrometry Data for the pH Stability Test: Clinoptilolite (Page 2 of 4)

	pH of added water	Strontium ppb			StD%	Yttrium ppb			StD%	Silver ppb			StD%
Treatment 1	9	4.6	±	0.09	1.9	43.8	±	0.86	2.0	0.050	±	0.00	4.8
	8	2.6	±	0.06	2.2	28.2	±	0.49	1.7	0.052	±	0.00	6.3
	7	3.0	±	0.01	0.3	24.3	±	0.26	1.1	0.089	±	0.01	19.2
	6	2.9	±	0.02	0.6	58.6	±	0.39	0.7	0.070	±	0.00	9.7
	5	2.7	±	0.01	0.5	20.5	±	0.48	2.4	0.068	±	0.00	13.4
	48 hr	3.8	±	0.08	2.0	2.17	±	0.11	4.9	0.029	±	0.00	11.5
	Sat.	16.8	±	0.21	1.2	28.2	±	0.17	0.6	0.055	±	0.00	3.9
Treatment 2	9	3.0	±	0.04	1.2	1.88	±	0.06	3.3	0.172	±	0.01	9.7
	8	2.5	±	0.02	0.8	0.58	±	0.08	13.9	0.047	±	0.00	7.6
	7	2.9	±	0.02	0.6	0.61	±	0.02	3.1	0.113	±	0.01	11.5
	6	2.6	±	0.01	0.5	0.70	±	0.04	5.7	0.078	±	0.00	5.2
	5	3.7	±	0.06	1.6	1.87	±	0.08	4.4	0.108	±	0.01	10.1
	48 hr	3.7	±	0.04	1.2	4.06	±	0.14	3.5	<0.02			
	Sat.	11.3	±	0.08	0.7	2.33	±	0.02	0.9	0.108	±	0.00	8.1
Treatment 3	9	2.5	±	0.01	0.6	1.00	±	0.03	3.0	0.249	±	0.01	5.9
	8	2.4	±	0.03	1.1	0.71	±	0.02	3.3	0.116	±	0.00	5.6
	7	3.2	±	0.03	0.9	1.72	±	0.10	5.6	0.079	±	0.00	3.1
	6	2.2	±	0.04	1.7	0.61	±	0.04	5.8	0.187	±	0.02	12.1
	5	2.9	±	0.50	17.2	0.86	±	0.08	9.6	0.158	±	0.03	20.6
	48hr	3.6	±	0.05	1.4	2.64	±	0.07	2.8	0.054	±	0.00	17.1
	Sat.	11.5	±	0.19	1.7	4.30	±	0.09	2.2	0.145	±	0.00	3.2
		Cesium				Barium				Lanthanum			
Treatment 1	9	0.237	±	0.00	2.7	3.16	±	0.12	3.8	2.40	±	0.06	2.5
	8	0.230	±	0.00	1.8	1.52	±	0.03	1.8	1.48	±	0.04	2.4
	7	0.242	±	0.00	0.4	3.04	±	0.09	3.0	2.77	±	0.44	15.8
	6	0.230	±	0.00	1.3	1.57	±	0.03	2.2	1.28	±	0.10	7.7
	5	0.241	±	0.00	1.1	1.40	±	0.04	2.7	1.20	±	0.05	3.9
	48 hr	0.230	±	0.00	0.3	6.05	±	0.05	0.8	3.17	±	0.16	5.1
	Sat.	0.316	±	0.00	1.5	5.19	±	0.01	0.3	2.39	±	0.08	3.1
Treatment 2	9	0.317	±	0.00	1.7	1.17	±	0.01	1.0	1.05	±	0.04	4.1
	8	0.233	±	0.00	0.7	0.75	±	0.01	1.1	0.53	±	0.05	10.1
	7	0.237	±	0.00	2.3	0.93	±	0.04	4.1	0.66	±	0.08	12.1
	6	0.237	±	0.00	1.4	1.03	±	0.01	1.4	0.74	±	0.02	2.5
	5	0.246	±	0.00	1.2	3.30	±	0.04	1.3	0.94	±	0.14	15.1
	48 hr	0.234	±	0.00	1.6	8.64	±	0.09	1.0	5.56	±	0.12	2.1
	Sat.	0.246	±	0.00	1.1	7.81	±	0.10	1.2	2.61	±	0.04	1.5
Treatment 3	9	0.259	±	0.00	1.5	3.23	±	0.00	0.0	1.04	±	0.09	8.6
	8	0.240	±	0.00	3.1	0.94	±	0.02	2.3	0.88	±	0.09	9.7
	7	0.326	±	0.00	2.1	1.83	±	0.07	4.0	2.00	±	0.05	2.4
	6	0.242	±	0.00	1.7	0.80	±	0.03	3.3	0.82	±	0.05	6.5
	5	0.534	±	0.14	27.4	1.75	±	0.23	13.3	0.87	±	0.12	13.5
	48 hr	0.232	±	0.00	1.4	6.11	±	0.05	0.7	3.32	±	0.23	7.0
	Sat.	0.273	±	0.00	1.1	7.80	±	0.02	0.3	4.39	±	0.18	4.1

Table D-5d. Inductively Coupled Plasma-Mass Spectrometry Data for the pH Stability Test: Clinoptilolite (Page 3 of 4)

	pH of added water	Cerium ppb			StD%	Praeseodymium ppb			StD%	Samarium ppb			StD%
Treatment 1	9	5.34	±	0.21	4.0	0.57	±	0.08	15.5	0.43	±	0.15	36
	8	2.92	±	0.07	2.5	0.31	±	0.04	15.8	0.36	±	0.15	42
	7	5.48	±	0.04	0.7	0.60	±	0.02	3.4	0.55	±	0.12	21
	6	2.82	±	0.07	2.6	0.30	±	0.01	4.6	0.21	±	0.09	42
	5	2.87	±	0.12	4.4	0.26	±	0.02	10.7	0.28	±	0.07	25
	48 hr	11.95	±	0.28	2.3	0.78	±	0.00	0.7	0.81	±	0.24	30
	Sat.	6.44	±	0.17	2.7	0.64	±	0.02	4.3	0.81	±	0.32	39
Treatment 2	9	2.51	±	0.08	3.3	0.22	±	0.01	6.3	0.43	±	0.03	8
	8	1.33	±	0.13	9.5	0.13	±	0.01	13.1	0.23	±	0.07	31
	7	1.72	±	0.05	3.2	0.17	±	0.01	7.5	0.23	±	0.19	85
	6	1.94	±	0.06	3.2	0.17	±	0.01	9.5	0.22	±	0.07	33
	5	2.13	±	0.05	2.4	0.24	±	0.00	2.2	0.41	±	0.27	65
	48 hr	20.20	±	0.48	2.4	1.40	±	0.05	3.7	1.36	±	0.07	5
	Sat.	7.96	±	0.06	0.7	0.72	±	0.05	7.7	1.03	±	0.18	17
Treatment 3	9	2.21	±	0.07	3.2	0.24	±	0.03	12.8	0.11	±	0.11	95
	8	1.91	±	0.11	5.8	0.20	±	0.01	6.5	0.13	±	0.12	92
	7	4.94	±	0.16	3.2	0.51	±	0.02	4.2	0.42	±	0.14	35
	6	2.08	±	0.15	7.2	0.19	±	0.03	19.2	0.20	±	0.07	33
	5	2.52	±	0.64	25.2	0.25	±	0.01	5.0	0.41	±	0.23	56
	48 hr	11.33	±	0.19	1.7	0.88	±	0.09	10.6	0.78	±	0.10	13
	Sat.	13.23	±	0.39	2.9	1.19	±	0.03	2.8	1.23	±	0.19	15
		Europium				Gadolinium				Dysprosium			
Treatment 1	9	0.154	±	0.03	24	3.74	±	0.18	5	0.73	±	0.11	14
	8	<0.05				1.20	±	0.10	9	0.35	±	0.12	33
	7	0.096	±	0.03	34	0.81	±	0.04	5	0.63	±	0.08	12
	6	0.060	±	0.01	21	6.19	±	0.22	4	0.24	±	0.06	26
	5	<0.05				0.98	±	0.07	7	0.33	±	0.03	9
	48 hr	0.112	±	0.03	31	0.89	±	0.07	7	0.75	±	0.11	15
	Sat.	0.124	±	0.03	25	3.91	±	0.07	2	0.64	±	0.11	17
Treatment 2	9	0.057	±	0.02	50	3.35	±	0.28	8	1.11	±	0.07	6
	8	<0.05				0.45	±	0.06	12	0.65	±	0.03	5
	7	<0.05				1.12	±	0.14	12	0.81	±	0.10	13
	6	<0.05				0.56	±	0.13	23	1.04	±	0.09	8
	5	0.070	±	0.04	62	5.17	±	0.15	3	0.75	±	0.08	11
	48 hr	0.214	±	0.02	11	1.55	±	0.14	9	1.42	±	0.19	13
	Sat.	0.181	±	0.03	22	1.73	±	0.13	7	2.10	±	0.10	5
Treatment 3	9	<0.05				2.91	±	0.16	6	0.54	±	0.01	2
	8	<0.05				0.58	±	0.02	3	0.68	±	0.04	6
	7	0.065	±	0.03	49	1.60	±	0.10	6	0.65	±	0.03	5
	6	<0.05				0.31	±	0.06	19	0.59	±	0.05	9
	5	0.069	±	0.01	27	1.34	±	0.24	18	0.76	±	0.05	7
	48 hr	0.138	±	0.01	12	0.76	±	0.09	12	0.70	±	0.12	17
	Sat.	0.203	±	0.00	4	2.64	±	0.26	10	1.35	±	0.05	4

Table D-5d. Inductively Coupled Plasma-Mass Spectrometry Data for the pH Stability Test: Clinoptilolite (Page 4 of 4)

	pH	Holmium				Erbium				Lead			
	of added water	ppb			StD%	ppb			StD%	ppb			StD%
Treatment 1	9	0.099	±	0.017	17	0.40	±	0.03	8	1.18	±	0.05	4.3
	8	0.034	±	0.008	23	0.16	±	0.05	31	0.31	±	0.02	8.5
	7	0.094	±	0.024	26	0.40	±	0.02	5	0.42	±	0.02	5.1
	6	0.050	±	0.011	22	0.16	±	0.05	34	0.43	±	0.00	0.8
	5	0.056	±	0.016	29	0.11	±	0.10	89	0.35	±	0.02	5.8
	48 hr	0.110	±	0.004	3	0.49	±	0.08	15	0.62	±	0.00	1.4
	Sat.	0.102	±	0.021	20	0.37	±	0.08	21	1.05	±	0.01	1.2
Treatment 2	9	0.044	±	0.010	22	0.13	±	0.03	27	0.23	±	0.01	5.7
	8	<0.02				0.05	±	0.01	13	0.22	±	0.00	2.1
	7	0.024	±	0.012	48	0.04	±	0.03	83	0.16	±	0.00	2.5
	6	0.032	±	0.009	28	0.09	±	0.05	54	0.23	±	0.01	7.3
	5	0.053	±	0.036	67	0.15	±	0.10	68	0.29	±	0.00	3.1
	48 hr	0.200	±	0.016	8	0.79	±	0.11	14	1.55	±	0.05	3.4
	Sat.	0.153	±	0.011	7	0.41	±	0.09	23	0.80	±	0.05	7.1
Treatment 3	9	<0.02				0.10	±	0.05	53	0.21	±	0.02	9.5
	8	0.034	±	0.012	36	0.16	±	0.04	24	0.43	±	0.02	5.3
	7	0.080	±	0.014	17	0.20	±	0.04	18	0.41	±	0.04	10.1
	6	0.043	±	0.012	27	0.06	±	0.04	63	0.28	±	0.01	4.3
	5	0.055	±	0.043	78	0.19	±	0.02	12	0.27	±	0.01	5.8
	48 hr	0.123	±	0.032	26	0.32	±	0.12	36	0.68	±	0.03	5.5
	Sat.	0.176	±	0.021	12	0.55	±	0.05	9	2.68	±	0.02	0.8

Table D-5e. Inductively Coupled Plasma-Mass Spectrometry Data for the pH Stability Test: Hanford Soil (Page 1 of 4)

	pH of added water	Chromium ppb	StD%	Manganese ppb	StD%	Iron ppb	StD%
Treatment 1	9	6.1 ± 0.05	0.8	2.53 ± 0.04	1.5	232 ± 3.0	1.3
	8	5.5 ± 0.07	1.3	1.62 ± 0.02	1.5	207 ± 5.7	2.8
	7	5.8 ± 0.27	4.7	5.17 ± 0.18	3.5	242 ± 11.0	4.6
	6	0.3 ± 0.02	6.9	0.44 ± 0.01	3.4	172 ± 1.9	1.1
	5	0.3 ± 0.03	9.1	0.22 ± 0.01	5.2	108 ± 3.1	2.9
	48 hr	0.4 ± 0.02	4.2	8.66 ± 0.09	1.1	206 ± 8.5	4.1
Treatment 2	9	92.1 ± 0.87	0.9	1.09 ± 0.01	1.2	243 ± 2.3	1.0
	8	88.6 ± 0.76	0.9	0.79 ± 0.01	1.7	234 ± 11.2	4.8
	7	95.2		0.64		245	
	6	102.4 ± 0.6	0.6	0.86 ± 0.02	2.5	284 ± 3.0	1.1
	5	111.9		0.75		286	
	48 hr	3.1 ± 0.10	3.2	5.10 ± 0.07	1.4	171 ± 6.1	3.6
Treatment 3	9	4.7 ± 0.08	1.6	1.63 ± 0.03	1.8	179 ± 6.4	3.6
	8	3.5 ± 0.05	1.4	1.52 ± 0.01	1.0	205 ± 1.8	0.9
	7	3.9 ± 0.03	0.7	2.34 ± 0.03	1.4	222 ± 3.5	1.6
	6	4.1		1.82		220	
	5	3.2		2.08		256	
	48 hr	1.2 ± 0.03	2.0	2.21 ± 0.02	1.0	198 ± 4.2	2.1

	pH of added water	Copper ppb	StD%	Zinc ppb	StD%	Arsenic ppb	StD%
Treatment 1	9	6.35 ± 0.08	1.2	4.78 ± 0.14	3.0	1.49 ± 0.02	1.3
	8	6.08 ± 0.16	2.6	6.97 ± 0.46	6.6	1.47 ± 0.04	2.8
	7	4.81 ± 0.07	1.4	8.80 ± 0.22	2.5	1.74 ± 0.00	0.3
	6	3.53 ± 0.08	2.3	5.14 ± 0.05	0.9	<0.05	
	5	1.30 ± 0.08	6.3	3.12 ± 0.08	2.7	<0.05	
	48 hr	2.88 ± 0.08	2.7	2.41 ± 0.15	6.1	0.31 ± 0.04	12.8
Treatment 2	9	3.04 ± 0.09	2.9	27.2 ± 0.49	1.8	2.43 ± 0.04	1.7
	8	1.89 ± 0.14	7.3	3.29 ± 0.16	5.0	2.27 ± 0.10	4.2
	7	1.35		2.87		2.30	
	6	3.21 ± 0.14	4.2	7.72 ± 0.30	3.9	2.05 ± 0.11	5.5
	5	1.70		10.0		2.15	
	48 hr	1.71 ± 0.09	5.0	10.1 ± 0.10	1.0	0.37 ± 0.03	7.5
Treatment 3	9	4.64 ± 0.18	4.0	8.51 ± 0.14	1.6	1.91 ± 0.04	2.2
	8	3.91 ± 0.12	3.2	9.69 ± 0.23	2.3	1.47 ± 0.04	2.6
	7	3.78 ± 0.09	2.3	7.24 ± 0.11	1.6	1.48 ± 0.03	2.3
	6	4.09		9.18		1.35	
	5	3.32		16.2		1.41	
	48 hr	2.19 ± 0.09	3.9	11.1 ± 0.10	0.9	0.50 ± 0.02	3.8

Table D-5e. Inductively Coupled Plasma-Mass Spectrometry Data for the pH Stability Test: Hanford Soil (Page 2 of 4)

	pH	Strontium				Yttrium				Silver			
	of added water	ppb			StD%	ppb			StD%	ppb			StD%
Treatment 1	9	118	±	0.81	0.7	0.20	±	0.03	16.0	<0.02			
	8	105	±	0.53	0.5	0.16	±	0.01	7.9	0.030	±	0.005	14.9
	7	94.3	±	2.26	2.4	0.53	±	0.03	6.5	<0.02			
	6	9.3	±	0.15	1.6	0.11	±	0.01	7.6	0.021	±	0.004	20.2
	5	4.6	±	0.07	1.5	0.06	±	0.02	30.8	<0.02			
	48 hr	74.5	±	1.8	2.4	0.07	±	0.01	19.2	0.036	±	0.005	14.0
Treatment 2	9	81.4	±	0.48	0.6		na			<0.02			
	8	92.5	±	3.5	3.8		na			0.062	±	0.006	10.0
	7	88.5					na			0.103			
	6	104	±	1.5	1.4		na			0.094	±	0.020	21.7
	5	101					na			0.061			
	48 hr	55.7	±	0.45	0.8	0.24	±	0.04	18.4	0.025	±	0.005	20.4
Treatment 3	9	83.4	±	1.3	1.5	6.34	±	0.17	2.7	<0.02			
	8	96.2	±	0.89	0.9	10.4	±	0.11	1.0	<0.02			
	7	101	±	0.55	0.5	5.24	±	0.18	3.3	<0.02			
	6	99.0				7.30				<0.02			
	5	110				6.65				<0.02			
	48 hr	67.8	±	0.67	1.0	0.27	±	0.03	12.0	<0.02			
		Cesium				Barium				Lanthanum			
Treatment 1	9	0.360	±	0.011	3.0	23.1	±	0.28	1.2	0.11	±	0.01	10.4
	8	0.549	±	0.013	2.3	21.4	±	0.43	2.0	<0.1			
	7	0.243	±	0.005	2.0	19.7	±	0.34	1.7	0.39	±	0.06	15.6
	6	0.243	±	0.001	0.5	0.85	±	0.01	1.7	<0.1			
	5	0.249	±	0.003	1.2	0.13	±	0.02	17.5	<0.1			
	48 hr	0.217	±	0.005	2.2	12.8	±	0.25	2.0	<0.1			
Treatment 2	9	0.217	±	0.006	3.0	14.1	±	0.21	1.5	0.19	±	0.01	3.8
	8	0.197	±	0.004	2.0	14.3	±	0.35	2.4	<0.1			
	7	0.236				13.6				<0.1			
	6	0.228	±	0.005	2.2	15.3	±	0.13	0.9	<0.1			
	5	0.230				18.9				0.13			
	48 hr	0.239	±	0.001	0.3	10.1	±	0.05	0.5	<0.1			
Treatment 3	9	0.235	±	0.002	1.0	13.6	±	0.13	0.9	<0.1			
	8	0.234	±	0.004	1.7	18.0	±	0.41	2.3	<0.1			
	7	0.260	±	0.003	1.2	19.1	±	0.28	1.5	0.17	±	0.06	34.2
	6	0.227				19.6				<0.1			
	5	0.234				22.1				<0.1			
	48 hr	0.240	±	0.004	1.5	14.4	±	0.12	0.8	<0.1			

Table D-5e. Inductively Coupled Plasma-Mass Spectrometry Data for the pH Stability Test: Hanford Soil (Page 3 of 4)

	pH of added water	Cerium ppb			StD%	Praeseodymium ppb			StD%	Samarium ppb			StD%
Treatment 1	9	0.10	±	0.02	19.0	<0.05				<0.05			
	8	<0.1				<0.05				0.07	±	0.04	58
	7	0.85	±	0.03	3.7	0.10	±	0.015	14.3	0.12	±	0.06	55
	6	0.15	±	0.01	7.6	<0.05				0.09	±	0.05	55
	5	<0.1				<0.05				0.06	±	0.06	93
	48 hr	<0.1				<0.05				0.08	±	0.01	17
Treatment 2	9	0.25	±	0.03	12.5	<0.05				0.06	±	0.09	162
	8	<0.1				<0.05				0.10	±	0.08	73
	7	<0.1				<0.05				0.07			
	6	<0.1				<0.05				0.05	±	0.03	58
	5	0.11				<0.05				<0.05			
	48 hr	0.13	±	0.01	11.3	<0.05				0.08	±	0.06	73
Treatment 3	9	0.11	±	0.02	16.9	<0.05				0.10	±	0.01	6
	8	<0.1				<0.05				<0.05			
	7	0.18	±	0.02	11.8	<0.05				0.07	±	0.04	62
	6	<0.1				<0.05				0.05			
	5	<0.1				0.05				0.00			
	48 hr	<0.1				<0.05				0.06	±	0.03	55
		Europium				**Gadolinium**				**Dysprosium**			
Treatment 1	9	<0.05				0.05	±	0.02	40	0.12	±	0.05	40
	8	0.093	±	0.008	9	0.07	±	0.01	17	0.14	±	0.04	28
	7	0.069	±	0.008	11	0.13	±	0.03	27	0.15	±	0.01	5
	6	<0.05				0.06	±	0.01	13	0.11	±	0.06	53
	5	<0.05				0.07	±	0.01	20	0.17	±	0.03	19
	48 hr	<0.05				0.08	±	0.06	76	<0.02			
Treatment 2	9	0.080	±	0.017	22	0.07	±	0.03	46	0.43	±	0.08	19
	8	<0.05				0.06	±	0.03	51	0.09	±	0.06	73
	7	<0.05				0.05				0.08			
	6	0.055	±	0.019	35	0.09	±	0.02	22	0.16	±	0.03	17
	5	0.106				0.06				0.10			
	48 hr	<0.05				0.08	±	0.01	8	0.13	±	0.05	40
Treatment 3	9	<0.05				0.12	±	0.05	45	0.17	±	0.04	25
	8	0.073	±	0.023	31	0.05	±	0.04	68	0.16	±	0.10	60
	7	0.070	±	0.025	36	0.14	±	0.09	63	0.15	±	0.04	28
	6	0.076				0.11				0.18			
	5	0.100				0.08				0.10			
	48 hr	0.063	±	0.009	15	0.09	±	0.08	89	0.15	±	0.01	9

Table D-5e. Inductively Coupled Plasma-Mass Spectrometry Data for the pH Stability Test: Hanford Soil (Page 4 of 4)

	pH of added water	Holmium ppb			StD%	Erbium ppb			StD%	Lead ppb			StD%
Treatment 1	9	0.024	±	0.003	14	0.06	±	0.02	45	<0.1			
	8	0.032	±	0.008	26	0.04	±	0.03	70	0.14	±	0.032	23.7
	7	0.037	±	0.011	31	0.07	±	0.03	38	0.10	±	0.023	21.9
	6	0.033	±	0.008	25	0.09	±	0.02	20	0.87	±	0.014	1.6
	5	0.034	±	0.027	78	0.03	±	0.04	120	0.12	±	0.002	1.3
	48 hr	<0.02				0.08	±	0.03	42	0.13	±	0.015	11.9
Treatment 2	9	0.023	±	0.002	7	0.03	±	0.00	9	1.04	±	0.049	4.7
	8	0.028	±	0.007	27	0.06	±	0.01	14	0.11	±	0.019	16.8
	7	0.035				<0.02				0.14			
	6	0.021	±	0.015	71	0.04	±	0.05	128	0.33	±	0.022	6.7
	5	<0.02				0.03				0.17			
	48 hr	0.026	±	0.019	73	0.04	±	0.03	71	0.28	±	0.005	1.7
Treatment 3	9	<0.02				0.05	±	0.04	84	0.21	±	0.014	6.5
	8	0.025	±	0.026	103	<0.02				<0.1			
	7	0.037	±	0.011	29	0.09	±	0.08	90	0.14	±	0.013	9.4
	6	<0.02				0.02				0.18			
	5	<0.02				0.02				<0.1			
	48 hr	<0.02				0.05	±	0.02	40	0.25	±	0.038	15.0

Table D-5f. Inductively Coupled Plasma-Mass Spectrometry Data for the pH Stability Test: Hanford Groundwater (Page 1 of 4)

	pH of added water	Chromium ppb			StD%	Manganese ppb			StD%	Iron ppb			StD%
Treatment 1	9	3.1	±	0.08	2.6	0.74	±	0.00	0.4	217	±	6.4	3.0
	8	0.2	±	0.02	6.8	0.39	±	0.02	4.6	156	±	3.2	2.1
	7	0.3	±	0.02	5.8	0.16	±	0.00	2.9	90	±	2.1	2.3
	6	0.3	±	0.01	2.2	0.18	±	0.01	2.9	102	±	3.4	3.3
	5	0.4	±	0.02	6.3	0.20	±	0.00	1.0	100	±	2.9	2.9
	48 h r, Sat.	0.5	±	0.01	3.0	1.61	±	0.02	1.1	796	±	11.5	1.4
Treatment 2	9	1.9	±	0.06	3.1	0.91	±	0.03	3.1	243	±	7.4	3.0
	8	2.6	±	0.04	1.7	0.38	±	0.00	0.2	143	±	1.4	1.0
	7	1.1	±	0.10	8.9	0.24	±	0.02	7.0	104	±	10.4	10.1
	6	0.7	±	0.05	8.1	0.57	±	0.01	1.3	136	±	5.0	3.7
	5	1.2	±	0.02	1.8	0.37	±	0.01	3.0	122	±	7.4	6.1
	48 hr, Sat.	1.1	±	0.10	8.5	0.50	±	0.03	6.2	220	±	20.9	9.5
Treatment 3	9	1.3	±	0.07	5.3	0.70	±	0.00	0.7	169	±	1.1	0.7
	8	0.4	±	0.03	7.7	0.39	±	0.00	0.7	153	±	2.7	1.7
	7	<0.2				0.21	±	0.01	3.1	106	±	2.0	1.9
	6	<0.2				0.32	±	0.00	0.8	110	±	0.4	0.4
	5	1.8	±	0.06	3.1	0.37	±	0.01	3.7	149	±	4.7	3.2
	48 h r, Sat.	<0.2				0.61	±	0.02	3.8	331	±	6.8	2.1
		Copper				**Zinc**				**Arsenic**			
Treatment 1	9	3.66	±	0.14	3.7	5.15	±	0.04	0.7	0.08	±	0.01	9.0
	8	3.31	±	0.01	0.4	5.21	±	0.12	2.3	<0.05			
	7	0.69	±	0.05	7.0	5.78	±	2.28	39.5	<0.05			
	6	1.27	±	0.09	7.0	2.64	±	0.10	3.8	<0.05			
	5	1.44	±	0.14	10.0	1.97	±	0.02	1.1	<0.05			
	48 hr, Sat.	3.47	±	0.12	3.4	7.86	±	0.29	3.7	<0.05			
Treatment 2	9	2.05	±	0.05	2.2	6.37	±	0.20	3.1	<0.05			
	8	2.09	±	0.39	18.8	11.4	±	0.64	5.6	<0.05			
	7	0.76	±	0.02	3.2	2.00	±	0.12	6.2	<0.05			
	6	1.78	±	0.04	2.3	5.87	±	0.06	1.0	<0.05			
	5	1.03	±	0.05	5.0	3.60	±	0.26	7.1	<0.05			
	48 hr, Sat.	2.13	±	0.17	7.9	1.23	±	0.15	12.1	<0.05			
Treatment 3	9	1.13	±	0.06	5.3	12.7	±	0.11	0.8	<0.05			
	8	1.15	±	0.08	7.0	2.82	±	0.09	3.1	<0.05			
	7	0.92	±	0.01	0.6	5.56	±	0.09	1.7	<0.05			
	6	0.63	±	0.03	4.8	4.80	±	0.12	2.6	<0.05			
	5	1.32	±	0.02	1.7	9.45	±	0.18	1.9	<0.05			
	48 hr, Sat.	1.34	±	0.05	3.5	11.7	±	0.25	2.1	<0.05			

Table D-5f. Inductively Coupled Plasma-Mass Spectrometry Data for the pH Stability Test: Hanford Groundwater (Page 2 of 4)

pH		Strontium				Yttrium				Silver			
	of added water	ppb			StD%	ppb			StD%	ppb			StD%
Treatment 1	9	10.7	±	0.16	1.5	0.22	±	0.02	7.8	<0.02			
	8	8.2	±	0.12	1.5	0.10	±	0.01	12.1	0.023	±	0.008	35.2
	7	3.7	±	0.05	1.4	0.09	±	0.02	19.5	0.118	±	0.008	6.7
	6	4.2	±	0.06	1.3	0.07	±	0.02	21.9	<0.02			
	5	4.3	±	0.12	2.8	0.23	±	0.05	19.7	<0.02			
	48 hr, Sat.	44.6	±	0.08	0.2	0.71	±	0.04	4.9	0.045	±	0.011	23.5
Treatment 2	9	4.6	±	0.08	1.7	0.21	±	0.03	13.6	<0.02			
	8	5.6	±	0.06	1.1	0.17	±	0.02	14.4	0.028	±	0.003	9.7
	7	3.7	±	0.16	4.4	0.12	±	0.02	19.9	<0.02			
	6	6.2	±	0.18	2.9	0.23	±	0.04	15.9	0.033	±	0.004	12.2
	5	4.3	±	0.02	0.4	0.28	±	0.03	11.9	<0.02			
	48 hr, Sat.	12.2	±	0.37	3.0	0.28	±	0.05	17.4	0.066	±	0.005	7.1
Treatment 3	9	7.9	±	0.04	0.5	0.31	±	0.04	12.4	<0.02			
	8	8.7	±	0.07	0.8	0.08	±	0.01	12.5	0.020	±	0.004	18.5
	7	5.3	±	0.08	1.6	0.10	±	0.03	25.7	<0.02			
	6	5.3	±	0.09	1.7	0.13	±	0.02	18.9	<0.02			
	5	7.2	±	0.03	0.5	0.26	±	0.02	7.0	<0.02			
	48 hr, Sat.	17.5	±	0.26	1.5	0.25	±	0.01	4.4	0.035	±	0.014	41.5
		Cesium				**Barium**				**Lanthanum**			
Treatment 1	9	0.228	±	0.007	2.9	1.10	±	0.05	4.2	0.25	±	0.05	21.5
	8	0.236	±	0.004	1.5	0.73	±	0.014	2.0	<0.1			
	7	0.215	±	0.002	1.1	0.05	±	0.006	11.3	<0.1			
	6	0.249	±	0.006	2.5	0.13	±	0.012	8.9	<0.1			
	5	0.227	±	0.005	2.1	0.13	±	0.005	3.9	<0.1			
	48 hr, Sat.	0.228	±	0.003	1.5	5.03	±	0.153	3.0	0.60	±	0.02	3.8
Treatment 2	9	0.229	±	0.002	0.8	0.23	±	0.020	8.6	0.17	±	0.03	15.0
	8	0.223	±	0.004	1.9	0.31	±	0.019	6.2	<0.1			
	7	0.217	±	0.006	2.9	0.08	±	0.016	20.6	<0.1			
	6	0.211	±	0.006	3.0	0.45	±	0.019	4.2	0.10	±	0.02	16.5
	5	0.214	±	0.009	4.4	0.18	±	0.025	14.1	0.11	±	0.03	29.4
	48 hr, Sat.	0.215	±	0.007	3.1	1.16	±	0.024	2.1	0.17	±	0.02	11.8
Treatment 3	9	0.225	±	0.005	2.1	0.63	±	0.011	1.7	0.15	±	0.01	4.4
	8	0.213	±	0.009	4.3	0.73	±	0.039	5.3	<0.1			
	7	0.220	±	0.005	2.4	0.29	±	0.012	4.2	<0.1			
	6	0.212	±	0.002	1.0	0.28	±	0.011	4.0	<0.1			
	5	0.221	±	0.003	1.5	0.55	±	0.008	1.4	0.13	±	0.02	13.1
	48 hr, Sat.	0.218	±	0.004	1.9	1.71	±	0.040	2.3	0.16	±	0.03	15.9

Table D-5f. Inductively Coupled Plasma-Mass Spectrometry Data for the pH Stability Test: Hanford Groundwater (Page 3 of 4)

	pH of added water	Cerium ppb			StD%	Praeseodymium ppb			StD%	Samarium ppb			StD%
Treatment 1	9	0.49	±	0.06	13.0	0.07	±	0.026	37.4	0.10	±	0.03	27
	8	0.15	±	0.01	8.8	<0.05				0.05	±	0.03	53
	7	0.11	±	0.02	14.3	<0.05				<0.05			
	6	0.10	±	0.04	36.9	<0.05				0.08	±	0.04	50
	5	0.14	±	0.01	9.2	<0.05				0.11	±	0.11	102
	48 hr, Sat.	1.22	±	0.21	17.4	0.10	±	0.007	6.5	0.17	±	0.06	37
Treatment 2	9	0.39	±	0.01	2.8	<0.05				0.07	±	0.10	135
	8	0.14	±	0.03	20.1	<0.05				0.07	±	0.04	60
	7	0.12	±	0.02	20.3	<0.05				0.08	±	0.08	101
	6	0.22	±	0.03	14.3	<0.05				<0.05			
	5	0.23	±	0.03	12.0	<0.05				<0.05			
	48 hr, Sat.	0.31	±	0.08	25.2	<0.05				<0.05			
Treatment 3	9	0.31	±	0.04	12.3	<0.05				<0.05			
	8	<0.1				<0.05				0.08	±	0.04	46
	7	<0.1				<0.05				0.06	±	0.08	133
	6	<0.1				<0.05				0.05	±	0.06	122
	5	0.16	±	0.02	10.8	<0.05				0.06	±	0.05	94
	48 hr, Sat.	0.62	±	0.65	104.1	0.06	±	0.009	15.3	0.07	±	0.06	86
		Europium				**Gadolinium**				**Dysprosium**			
Treatment 1	9	0.089	±	0.012	13	0.20	±	0.07	36	0.14	±	0.03	19
	8	<0.05				0.09	±	0.02	17	0.09	±	0.05	58
	7	<0.05				0.18	±	0.07	41	0.04	±	0.05	142
	6	<0.05				0.09	±	0.06	63	0.04	±	0.03	76
	5	<0.05				0.08	±	0.03	36	0.11	±	0.06	58
	48 hr, Sat.	0.074	±	0.009	12	1.07	±	0.09	8	0.23	±	0.05	20
Treatment 2	9	<0.05				0.06	±	0.03	49	0.10	±	0.04	39
	8	<0.05				0.06	±	0.06	106	0.07	±	0.01	19
	7	<0.05				0.05	±	0.06	119	0.08	±	0.02	18
	6	0.053	±	0.029	54	0.05	±	0.02	34	0.16	±	0.07	41
	5	<0.05				0.06	±	0.03	47	0.12	±	0.05	42
	48 hr, Sat.	<0.05				0.22	±	0.08	38	0.13	±	0.07	50
Treatment 3	9	<0.05				0.12	±	0.01	12	0.14	±	0.03	25
	8	<0.05				0.04	±	0.03	81	0.05	±	0.01	27
	7	<0.05				0.07	±	0.04	50	0.05	±	0.01	15
	6	<0.05				0.06	±	0.03	53	0.82	±	0.09	11
	5	<0.05				0.08	±	0.02	23	0.21	±	0.06	30
	48 hr, Sat.	0.055	±	0.037	66	0.84	±	0.02	3	0.08	±	0.01	16

Table D-5f. Inductively Coupled Plasma-Mass Spectrometry Data for the pH Stability Test: Hanford Groundwater (Page 4 of 4)

	pH	Holmium				Erbium				Lead			
	of added water	ppb			StD%	ppb			StD%	ppb			StD%
Treatment 1	9	0.247	±	0.031	13	0.04	±	0.03	66	2.41	±	0.120	5.0
	8	<0.02				0.04	±	0.04	102	0.90	±	0.007	0.8
	7	0.020	±	0.005	22	<0.02				0.14	±	0.013	9.6
	6	0.022	±	0.003	15	0.03	±	0.05	174	0.11	±	0.003	2.3
	5	<0.02				0.05	±	0.01	25	0.64	±	0.034	5.2
	48 hr, Sat.	0.048	±	0.014	29	0.16	±	0.10	63	2.19	±	0.040	1.8
Treatment 2	9	0.071	±	0.037	51	0.07	±	0.07	98	1.01	±	0.028	2.8
	8	0.023	±	0.013	57	0.09	±	0.05	55	0.37	±	0.018	4.8
	7	<0.02				0.04	±	0.02	50	0.27	±	0.006	2.3
	6	0.021	±	0.006	28	0.03	±	0.03	90	1.21	±	0.055	4.6
	5	0.028	±	0.020	70	0.04	±	0.03	82	0.90	±	0.008	0.9
	48 hr, Sat.	0.024	±	0.006	24	0.04	±	0.06	135	0.58	±	0.017	2.9
Treatment 3	9	0.032	±	0.025	77	0.04	±	0.03	74	0.57	±	0.021	3.7
	8	<0.02				0.04	±	0.05	134	<0.1			
	7	<0.02				<0.02				0.75	±	0.015	1.9
	6	<0.02				0.06	±	0.01	20	0.18	±	0.015	8.2
	5	<0.02				0.04	±	0.07	189	0.85	±	0.036	4.2
	48 hr, Sat.	<0.02				0.08	±	0.02	23	0.65	±	0.014	2.1

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